



# TECHNICAL NOTE

## D-1327

STATIC AERODYNAMIC CHARACTERISTICS OF SHORT BLUNT  
CONES WITH VARIOUS NOSE AND BASE CONE ANGLES  
AT MACH NUMBERS FROM 0.6 TO 5.5 AND  
ANGLES OF ATTACK TO  $180^\circ$

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON

May 1962



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## SUMMARY

Wind-tunnel tests have been performed at Mach numbers from 0.6 to 5.5 to determine coefficients of normal force, axial force, and pitching moment for short blunt cones, as affected by changes in nose and base cone angles. Models with nose half-angles of  $10^\circ$  and  $20^\circ$  were investigated. The  $10^\circ$  nose half-angle models were tested with a flat base and with base cones of  $50^\circ$  and  $70^\circ$  half-angle. The  $20^\circ$  nose half-angle model had a  $50^\circ$  half-angle base cone. Reynolds numbers for the test ranged from about 0.6 to 1.8 million based on the model maximum diameter.

Variations in the base cone angle resulted in significant changes in the aerodynamic characteristics, with lesser effects resulting from changes in nose cone angle. In particular, the model with the  $50^\circ$  half-angle conical base had only one trim angle ( $\alpha = 0^\circ$ ), whereas the models with the flat base and  $70^\circ$  half-angle conical base had two trim angles ( $\alpha = 0^\circ$  and  $\alpha = 180^\circ$ ). Estimated variations of the aerodynamic characteristics with angle of attack by means of a modified Newtonian theory were in good agreement with the experimental results. The theory, however, failed to predict the trim point at  $\alpha = 180^\circ$  for the flat-based model.

## INTRODUCTION

The selection of a capsule shape for a freely falling instrument probe designed to survey planetary atmospheres involves a number of heat-transfer and aerodynamic considerations. To minimize the weight of the thermal protection system, the nose shape must be selected to keep the convective and radiative heat transfer low, and the capsule stability must be such that it will assume a nearly constant nose-first attitude during the portion of the entry flight where the heating rates are significant.

One configuration which, from a theoretical standpoint, appears to have the desired characteristics for a Mars probe is a short, blunt-nosed cone with a conical afterbody. In order to provide the necessary information to assess the suitability of this configuration for the intended mission, an extensive coordinated research program has been carried out at the Ames Research Center. The experimental portion of this program covered a range of Mach numbers of 0.6 to about 15 and consisted of wind-tunnel tests in air (the present report and ref. 1) and in helium, and tests in a free-flight facility (ref. 2). The results of these tests were then used in a motion-study analysis of probe entry into a model atmosphere of the planet Mars (ref. 3). The present report covers a wind-tunnel investigation of the effects of nose cone angle and base cone angle on the static aerodynamic characteristics of a blunt-nosed model. The angle of attack for the tests was varied through about  $180^\circ$  at Mach numbers from 0.6 to 5.5. Where appropriate, the results are compared with estimates according to modified Newtonian theory.

A  
5  
9  
3

## NOTATION

$C_A$	total axial-force coefficient, $\frac{\text{measured axial force}}{qS}$
$C_m$	pitching-moment coefficient about moment reference shown in figure 1, $\frac{\text{pitching moment}}{qSd}$
$C_N$	normal-force coefficient, $\frac{\text{normal force}}{qS}$
$d$	model maximum diameter
$M$	Mach number
$q$	dynamic pressure
$S$	cross-sectional area at model maximum diameter
$\alpha$	angle of attack
$\delta$	angle between model longitudinal axis and sting support, measured from nose forward attitude

## APPARATUS, TESTS, AND PROCEDURES

### Wind Tunnels

The experimental investigation was conducted in the Ames 2- by 2-Foot Transonic Wind Tunnel and the 1- by 3-Foot Supersonic Wind Tunnel. The 2- by 2-foot tunnel is a closed-circuit, variable-pressure wind tunnel having a flexible throat and a perforated test section which permit continuous choke-free operation up to about  $M = 1.4$ . The 1- by 3-foot supersonic tunnel is also a closed-circuit, variable-pressure type with a flexible-plate nozzle which provides a variation of Mach number from about 1.4 to 6.

### Tests

Wide ranges of angle of attack and Mach number were covered in the present investigation of the normal-force, pitching-moment, and axial-force characteristics of short blunt cones. Tests in the 2- by 2-foot transonic wind tunnel were conducted at Mach numbers of 0.6, 1.0, and 1.3 for angles of attack from about  $0^\circ$  to  $180^\circ$ . Reynolds numbers for these tests ranged from about 0.9 million to 1.2 million based on the model maximum diameter. Tests in the 1- by 3-foot tunnel were made at Mach numbers of 3.1 and 5.5, also for angles of attack of about  $0^\circ$  to  $180^\circ$ . Reynolds numbers for these higher Mach number tests were, in most cases, about 1.8 million at  $M = 3.1$  and about 0.6 million at  $M = 5.5$ .

Visualization of the flow about the models by means of the shadowgraph technique was employed as an aid in the interpretation of the force and moment data. Shadowgraph pictures were taken at selected test conditions and some of the pictures are presented later in the report.

### Reduction and Precision of Data

All the force and moment data have been reduced to coefficient form and are referred to the body axes system. Pitching-moment coefficients are taken about the model reference center shown in figure 1. All coefficients are based on the cross-sectional area corresponding to the model maximum diameter, and this diameter is taken as the reference length in the moment coefficients. No attempt was made to correct the measured results for possible support-interference effects. It is believed that such effects would be confined to the axial force as the sting support was immersed in the wake behind the model at all attitudes.

The precision of the final data is affected by uncertainties in the measurement of the forces and moments, and in the determination of the

stream static and dynamic pressures used in reducing the forces and the moments to coefficient form. These individual uncertainties result in estimated over-all uncertainties as follows:

$$\begin{array}{ll} C_N \pm 0.02 & \alpha \pm 0.1^\circ \\ C_A \pm 0.02 & M \pm 0.01 \\ C_m \pm 0.005 & \end{array}$$

### Models and Supports

Four models were used in the investigation and sketches of the models are presented in figure 1. Models 1, 2 and 3 were used in the investigation of base-cone-angle effects, and models 3 and 4 were used in the investigation of nose-cone-angle effects. Photographs of two of the models are shown in figure 2. In order to determine the aerodynamic loads throughout the extensive angle-of-attack range, the models were mounted in several attitudes on the foresection of a sting-supported strain-gage balance. Sketches of the model mountings are presented in figure 3. Included as part of figure 3 are the ranges of angle of attack for the various model mounting arrangements in both the 2- by 2-foot and 1- by 3-foot wind tunnels.

### RESULTS AND DISCUSSION

The experimental results of the investigation are presented in coefficient form as variations with angle of attack and Mach number. Values of  $C_N$ ,  $C_m$ , and  $C_A$  are presented in figures 4 through 7 for all of the models. The faired curves from these data are reproduced in figures 8 and 9 to show directly the effects of variations in the base cone angle and nose cone angle. Representative shadowgraphs are provided in figures 10 through 12.

#### Effects of Base Cone Angle

Variations of the base cone angle had significant effects on the aerodynamic characteristics except at the lower angles of attack (fig. 8). These effects are evidenced in both the levels of the coefficients and in their variations with angle of attack. Examples of the flow patterns are shown for models 1 and 3 in figures 10 and 11. Particularly noteworthy is

the fact that, except possibly at  $M = 0.6$ , the models with the flat base (model 1) and  $70^\circ$  half-angle base cone (model 2) have two regions of positive stability for the moment reference used with trim points at both  $\alpha = 0^\circ$  and  $\alpha = 180^\circ$ . In contrast, the model with the  $50^\circ$  half-angle base cone (model 3) had essentially only one trim point at  $\alpha = 0^\circ$ .

#### Effects of Nose Cone Angle

The effects of a change in nose cone half-angle from  $10^\circ$  (model 3) to  $20^\circ$  (model 4) are shown in figure 9. The relatively low axial-force coefficients for model 3 at low angles of attack and the lower Mach numbers indicate that it has a more streamlined shape even though it is blunter than model 4. At the higher Mach numbers, the bluntness of model 3 resulted in a higher pressure drag than that for model 4. Nose cone angle also had some effect on the variation of stability with Mach number at transonic speeds.

#### Comparison of Estimated and Experimental Values

Theoretical estimates of the static aerodynamic coefficients are presented for comparison with the experimental results at  $M = 3.1$  and  $M = 5.5$  in figures 4 through 7. These estimates were made by means of modified Newtonian theory, according to the method of reference 4, in which the stagnation pressure on the body was taken as the theoretical pressure behind a normal shock wave at the free-stream Mach number. With one noteworthy exception, the estimated variations of aerodynamic coefficients with angle of attack were generally in good agreement with the experimental results. The principal shortcoming of the theoretical estimates was the failure to indicate the trim point at  $180^\circ$  angle of attack for model 1.

#### CONCLUDING REMARKS

Wind-tunnel tests have been made at Mach numbers from 0.6 to 5.5 to investigate the effects of nose shape and base shape on the static aerodynamic characteristics of short blunt cones at angles of attack from  $0^\circ$  to  $180^\circ$ . Modifications of the model base shape produced significant changes in the aerodynamic characteristics. In particular, two of the models, one with a flat base and one with a  $70^\circ$  half-angle base cone, had trim points at both  $0^\circ$  and  $180^\circ$  angle of attack, whereas the model with a  $50^\circ$  half-angle base cone had a single trim point at  $0^\circ$  angle of attack. A change in the nose cone half-angle from  $10^\circ$  to  $20^\circ$  had no significant effects on the aerodynamic coefficients. The variations of the aerodynamic characteristics with angle of attack at  $M = 3.1$  and  $M = 5.5$  estimated

by means of a modified Newtonian theory were in generally good agreement with the experimental results. The theory, however, failed to predict the trim point at  $\alpha = 180^\circ$  for the flat-based model.

Ames Research Center

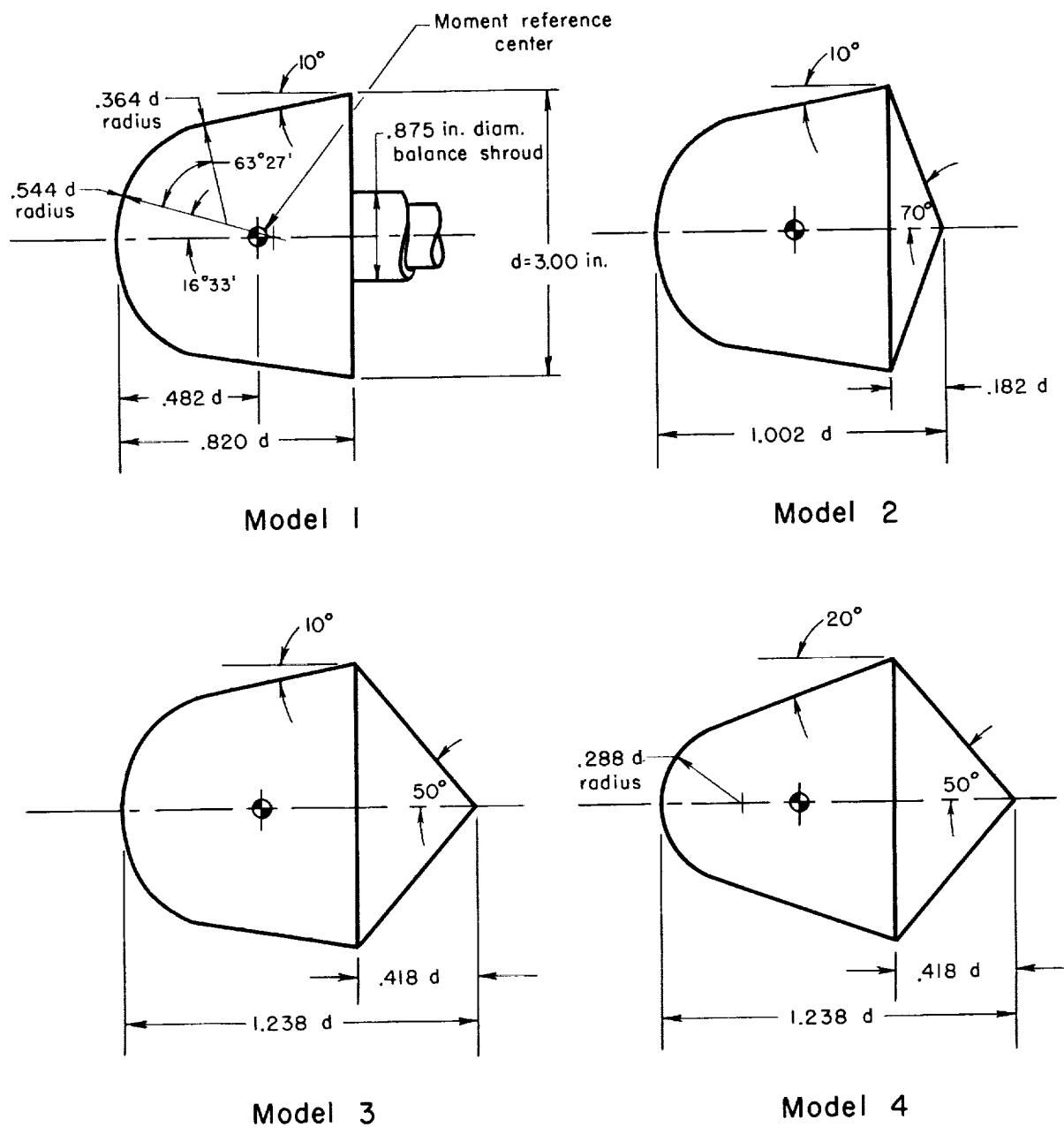
National Aeronautics and Space Administration

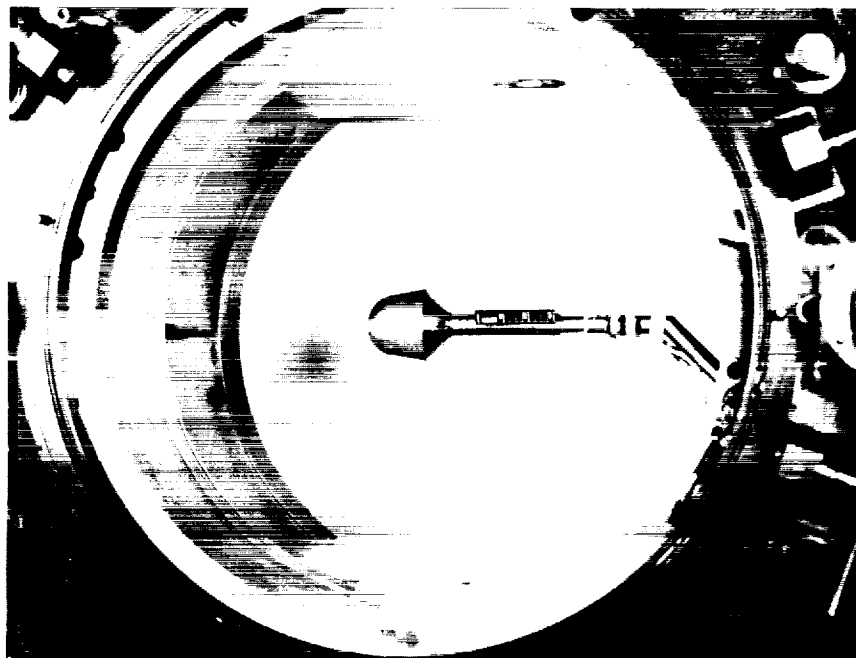
Moffett Field, Calif., Mar. 12, 1962

#### REFERENCES

1. Wehrend, William R., Jr.: Wind-Tunnel Investigation of the Static and Dynamic Stability Characteristics of a  $10^\circ$  Semivertex Angle Blunted Cone. NASA TN D-1202, 1962.
2. Intrieri, Peter F.: Free-Flight Measurements of the Static and Dynamic Stability and Drag of a  $10^\circ$  Blunted Cone at Mach Numbers 3.5 and 8.5. NASA TN D-1299, 1962.
3. Peterson, Victor L.: Motions of a Short  $10^\circ$  Blunted Cone Entering a Martian Atmosphere at Arbitrary Angles of Attack and Arbitrary Pitching Rates. NASA TN D-1326, 1962.
4. Margolis, Kenneth: Theoretical Evaluation of the Pressures, Forces, and Moments of Hypersonic Speeds Acting on Arbitrary Bodies of Revolution Undergoing Separate and Combined Angle-of-Attack and Pitching Motions. NASA TN D-652, 1961.

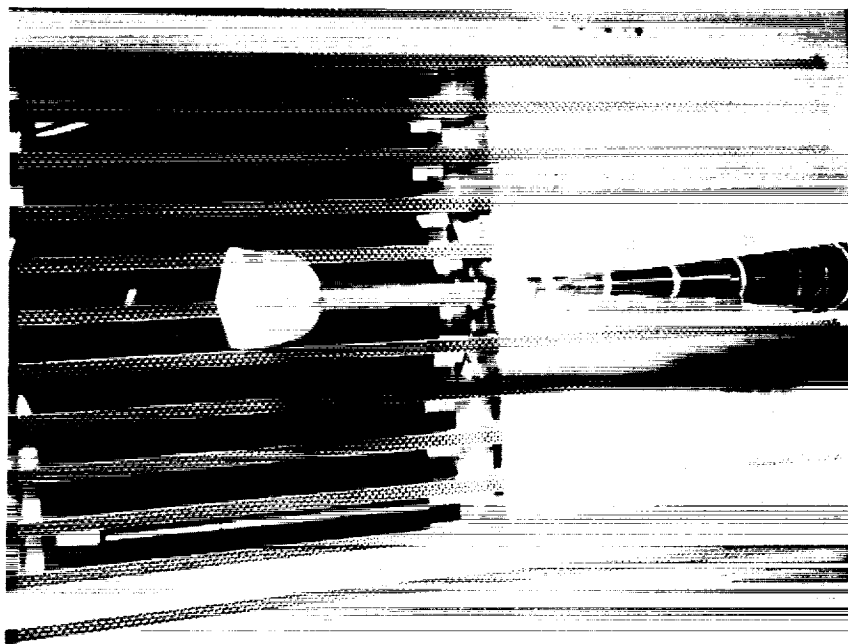






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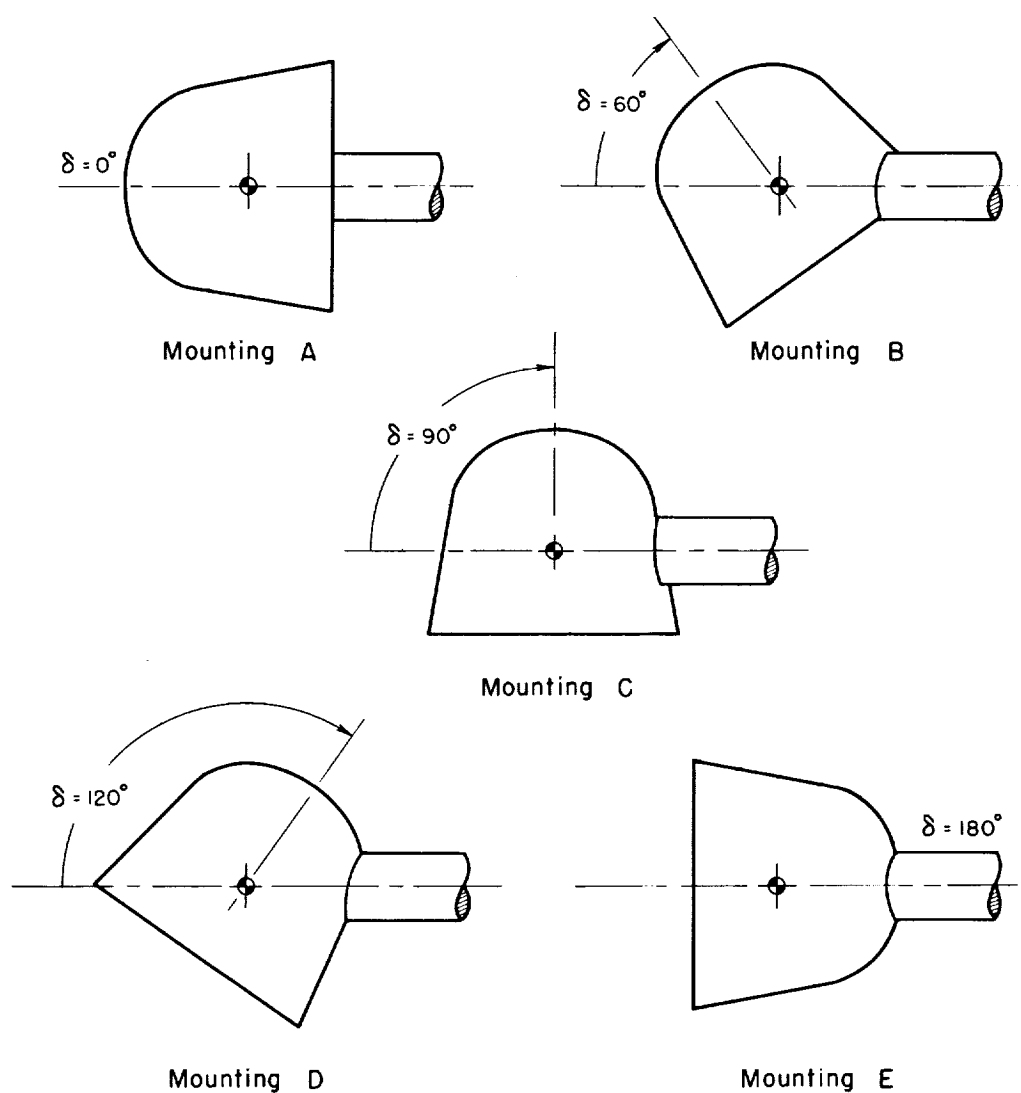
(a) Model 3 in the Ames 1- by 3-Foot Supersonic Wind Tunnel.



A-28570

(b) Model 2 in the Ames 2- by 2-Foot Transonic Wind Tunnel.

Figure 2.- Photographs of models in the wind tunnels.



Facility	M	Mounting	Approx. $\alpha$ range
2-by-2-foot T.W.T.	.6, 1.0, 1.3	A	$-2^\circ - 28^\circ$
		B	$36^\circ - 68^\circ$
		C	$66^\circ - 114^\circ$
		D	$112^\circ - 144^\circ$
		E	$152^\circ - 190^\circ$
1-by-3-foot W.T.	3.1, 5.5	A	$-4^\circ - 40^\circ$
		C	$60^\circ - 150^\circ$
		E	$150^\circ - 184^\circ$

Figure 3.- Model mountings and angle-of-attack ranges.

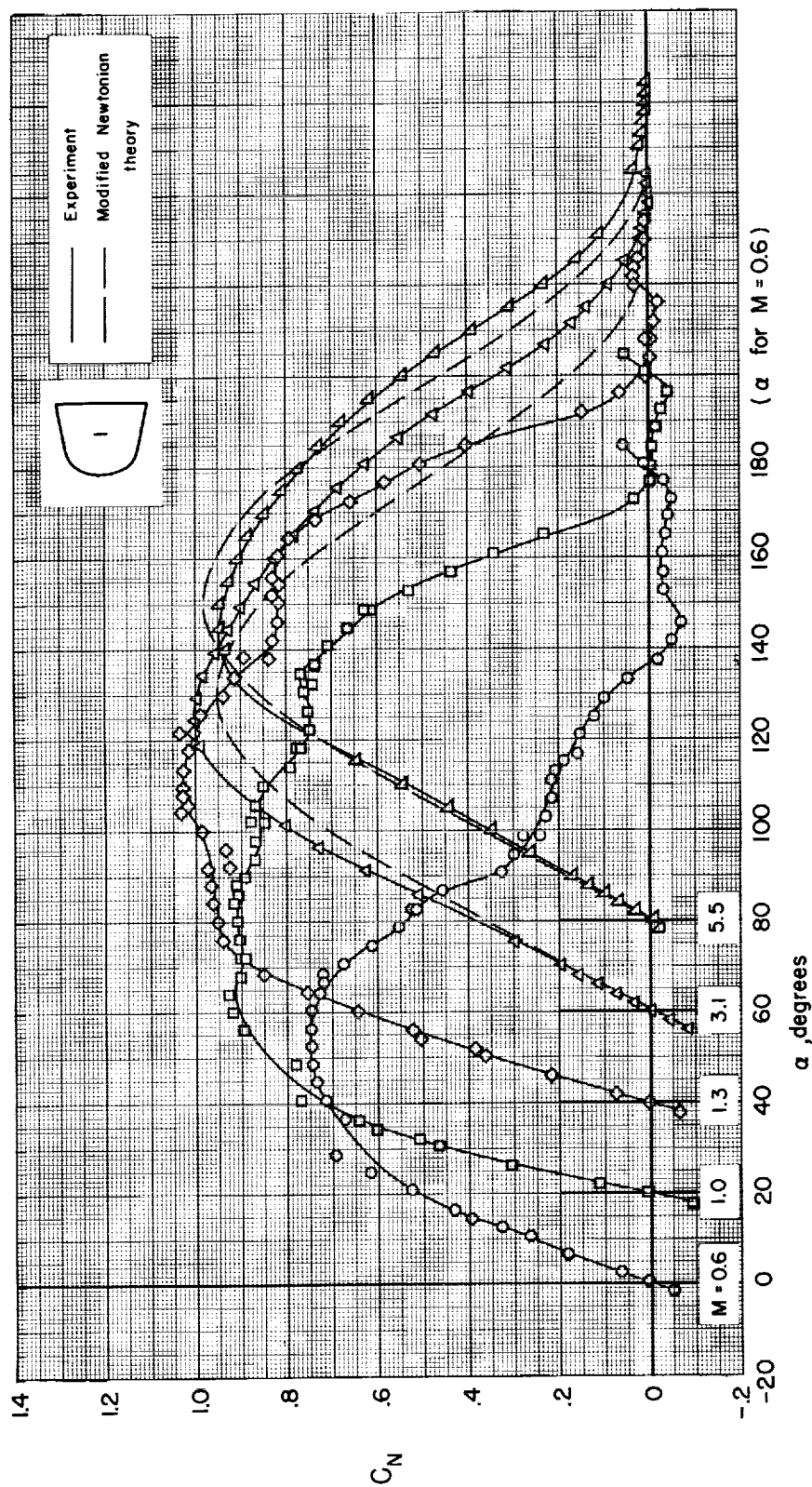
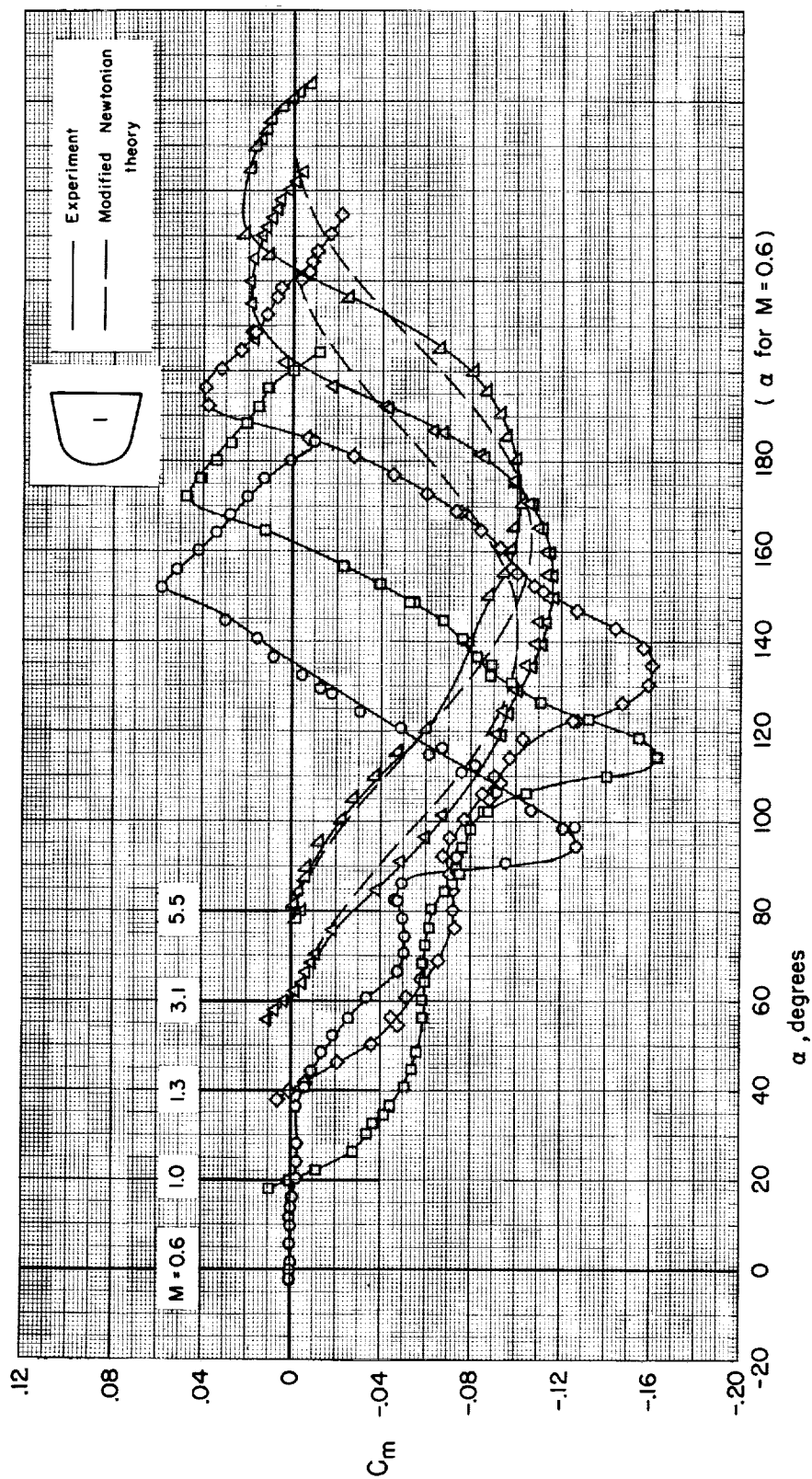
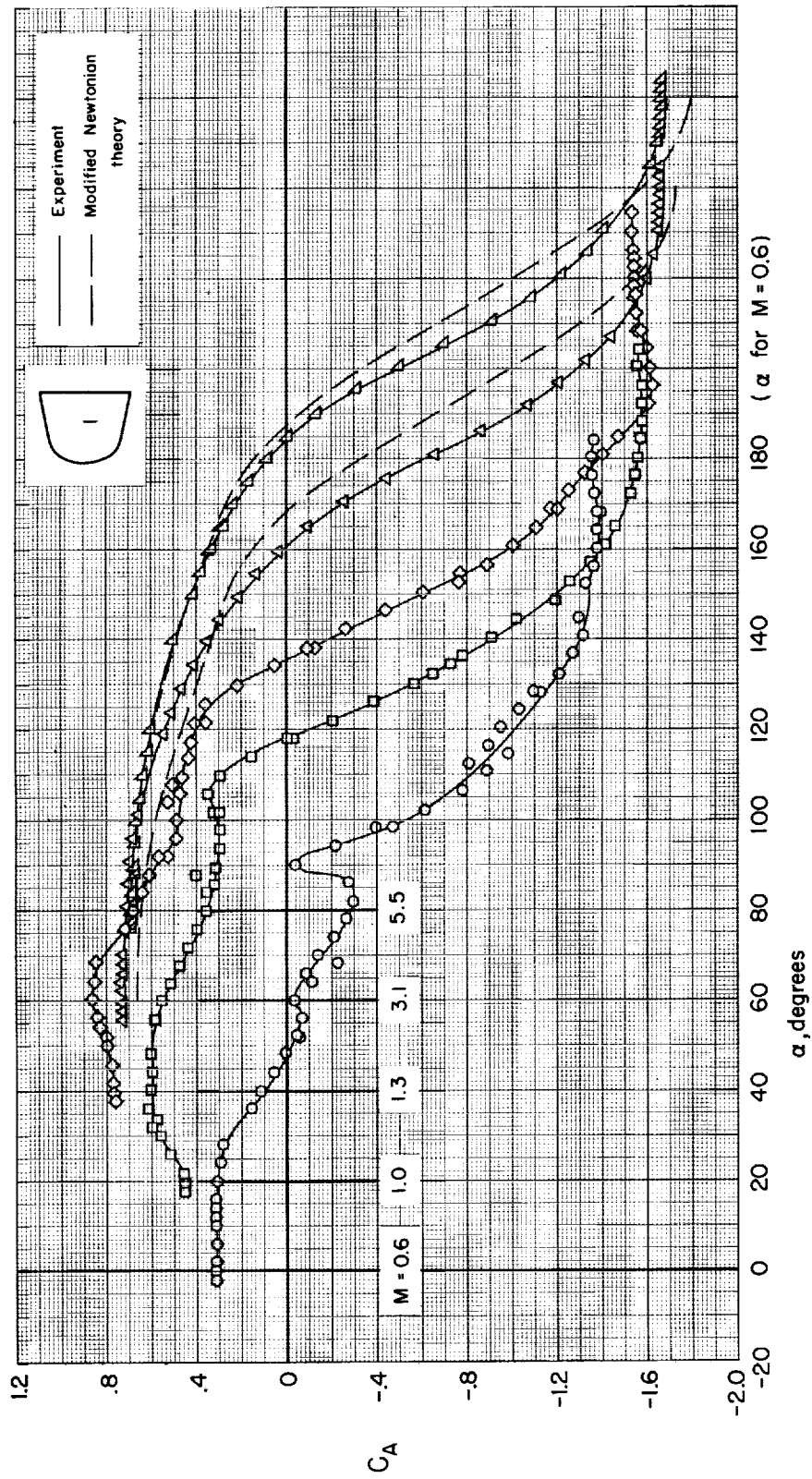
(a)  $C_N$  vs.  $\alpha$ 

Figure 4.- Static aerodynamic coefficients of model 1.



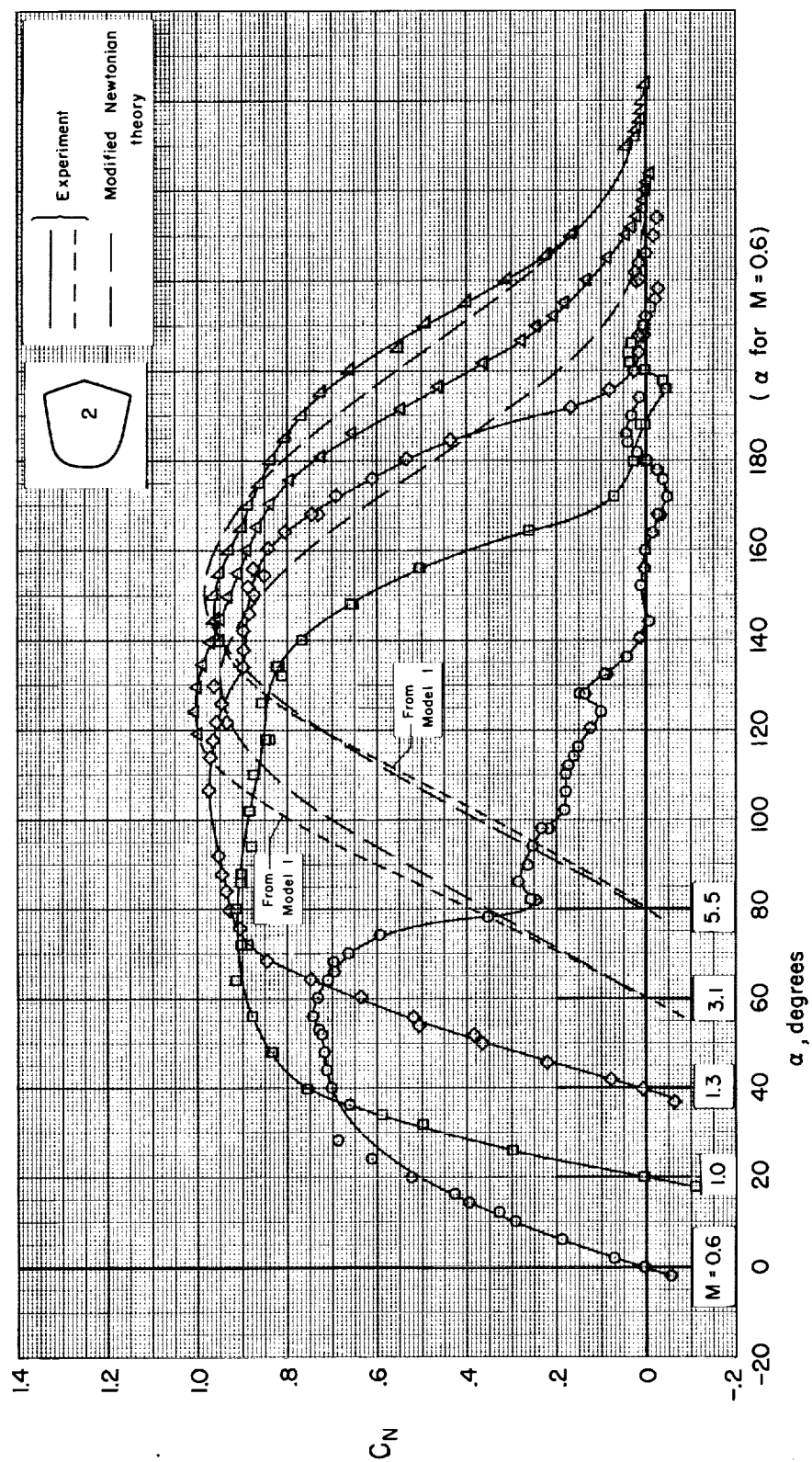
(b)  $C_m$  vs.  $\alpha$

Figure 4.- Continued.



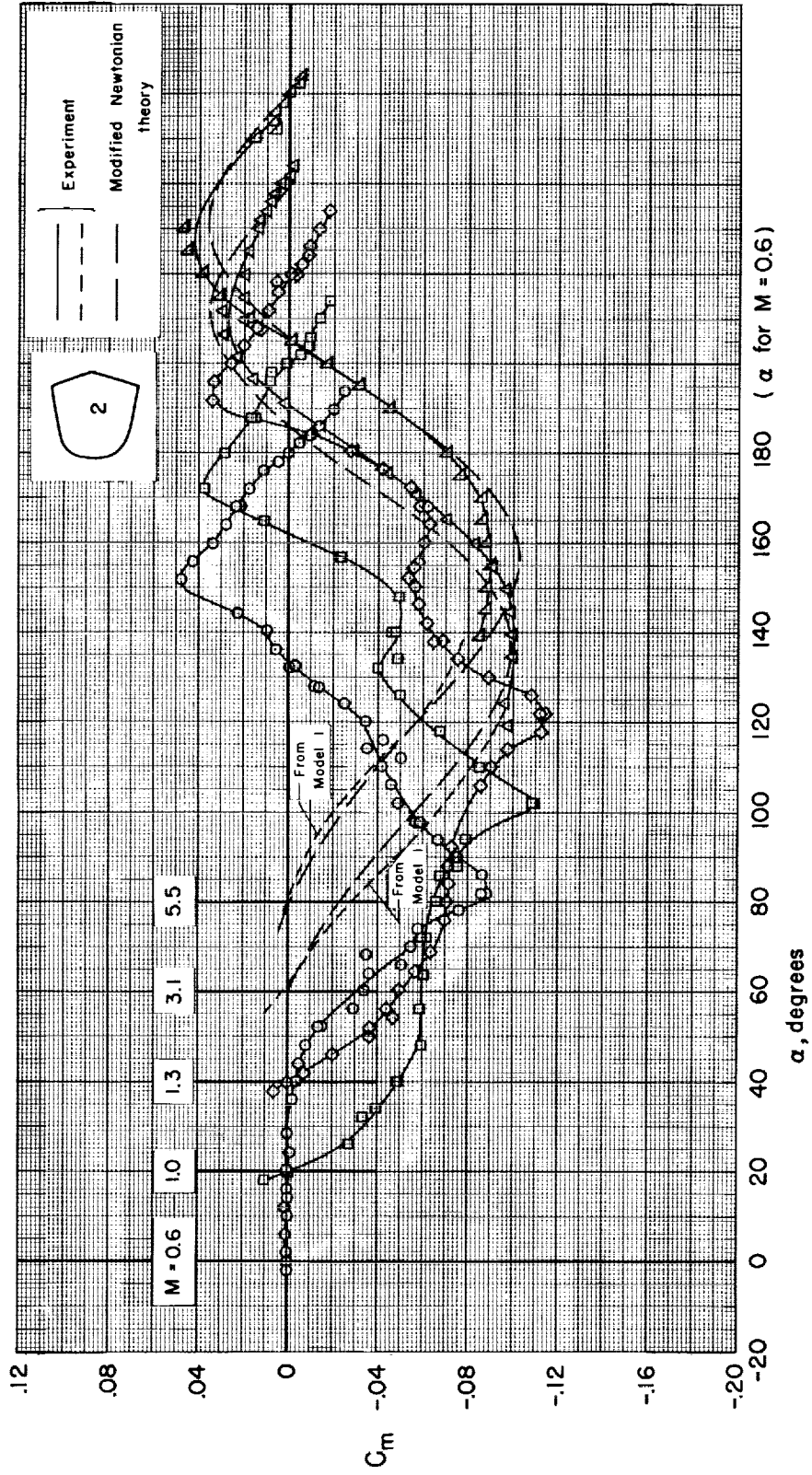
(c)  $C_A$  vs.  $\alpha$

Figure 4.- Concluded.



(a)  $C_N$  vs.  $\alpha$

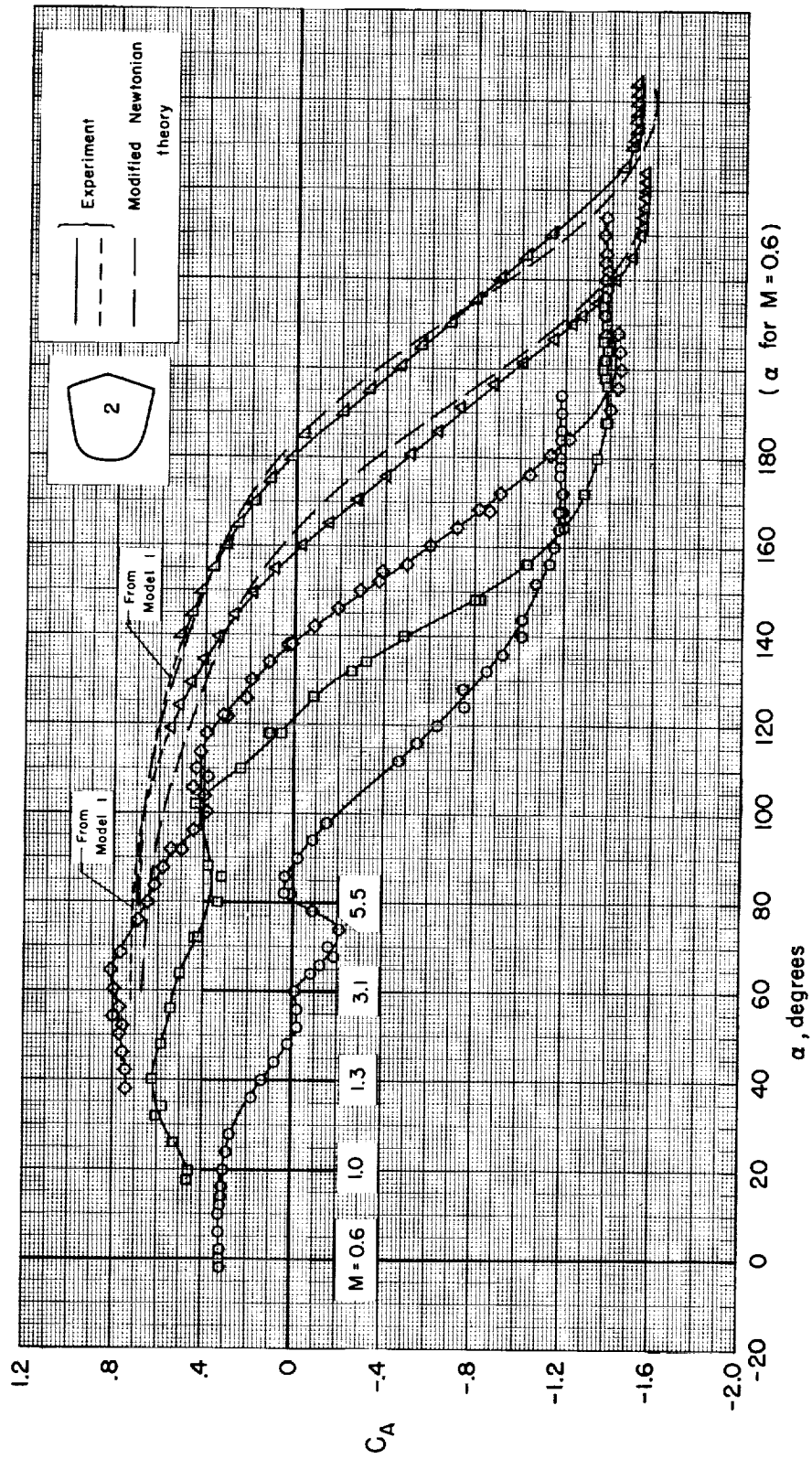
Figure 5.- Static aerodynamic coefficients of model 2.



(b)  $C_m$  vs.  $\alpha$

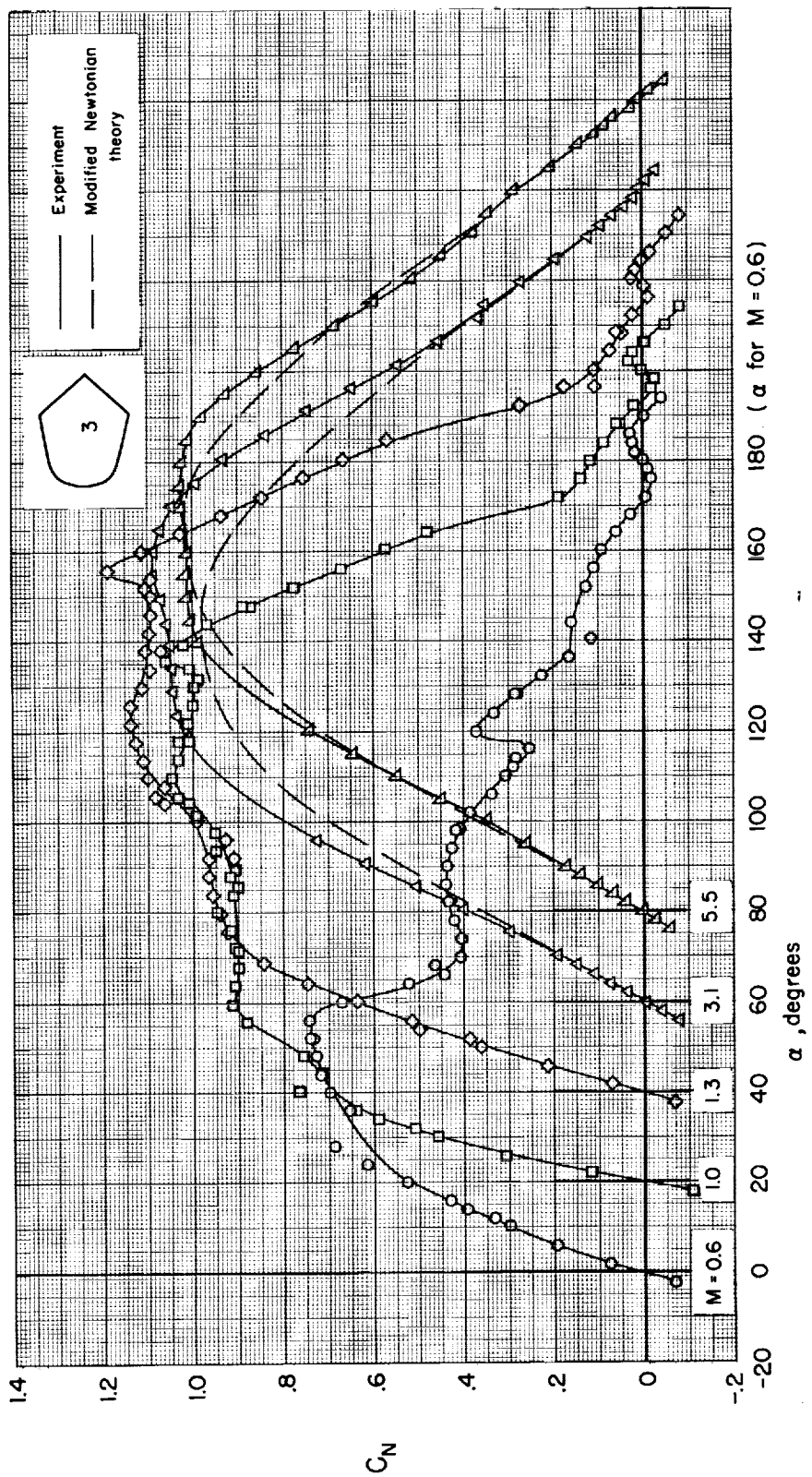
Figure 5.- Continued.





(c)  $C_A$  vs.  $\alpha$

Figure 5.- Concluded.



(a)  $C_N$  vs.  $\alpha$

Figure 6.- Static aerodynamic coefficients of model 3.

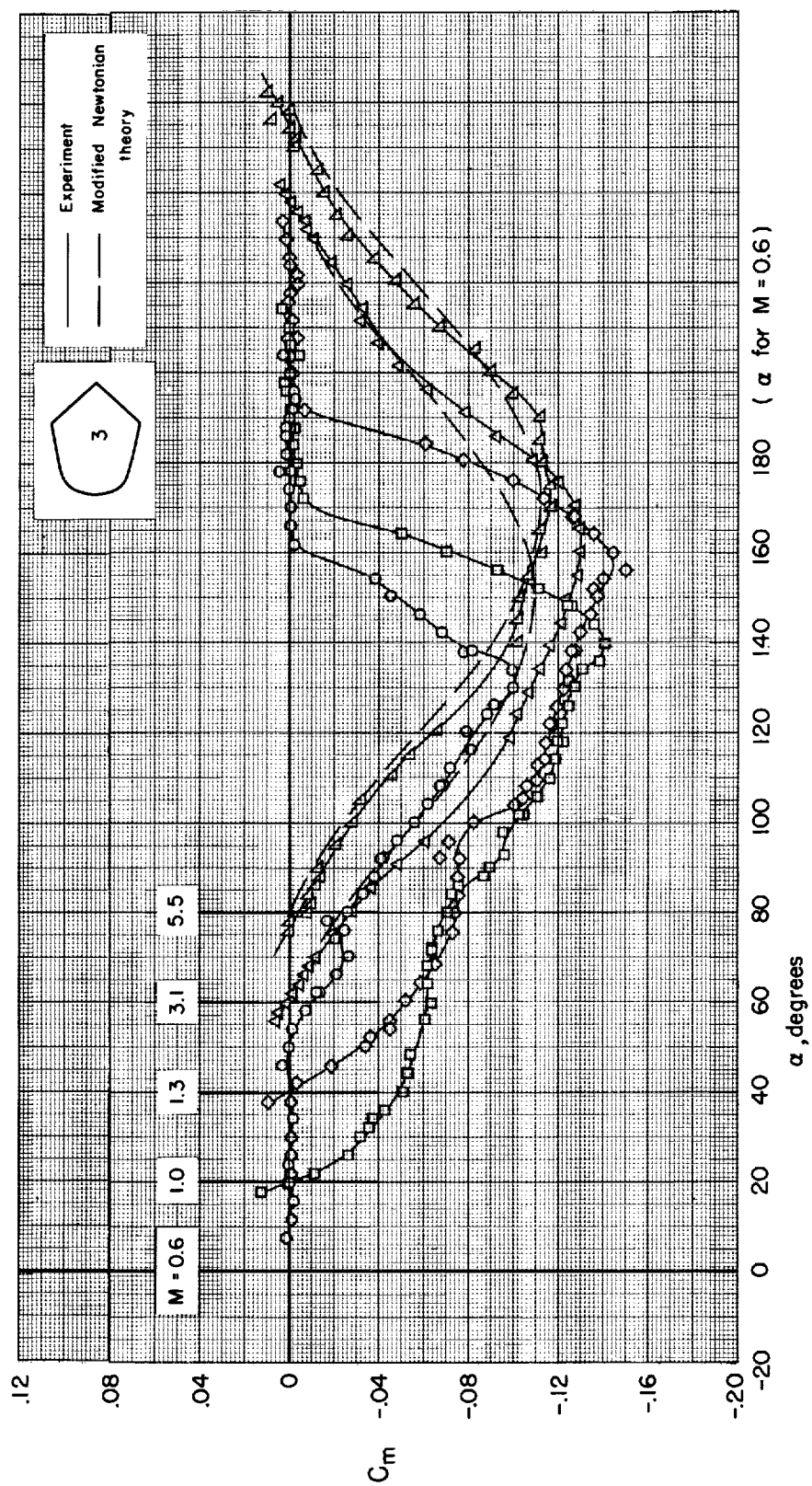
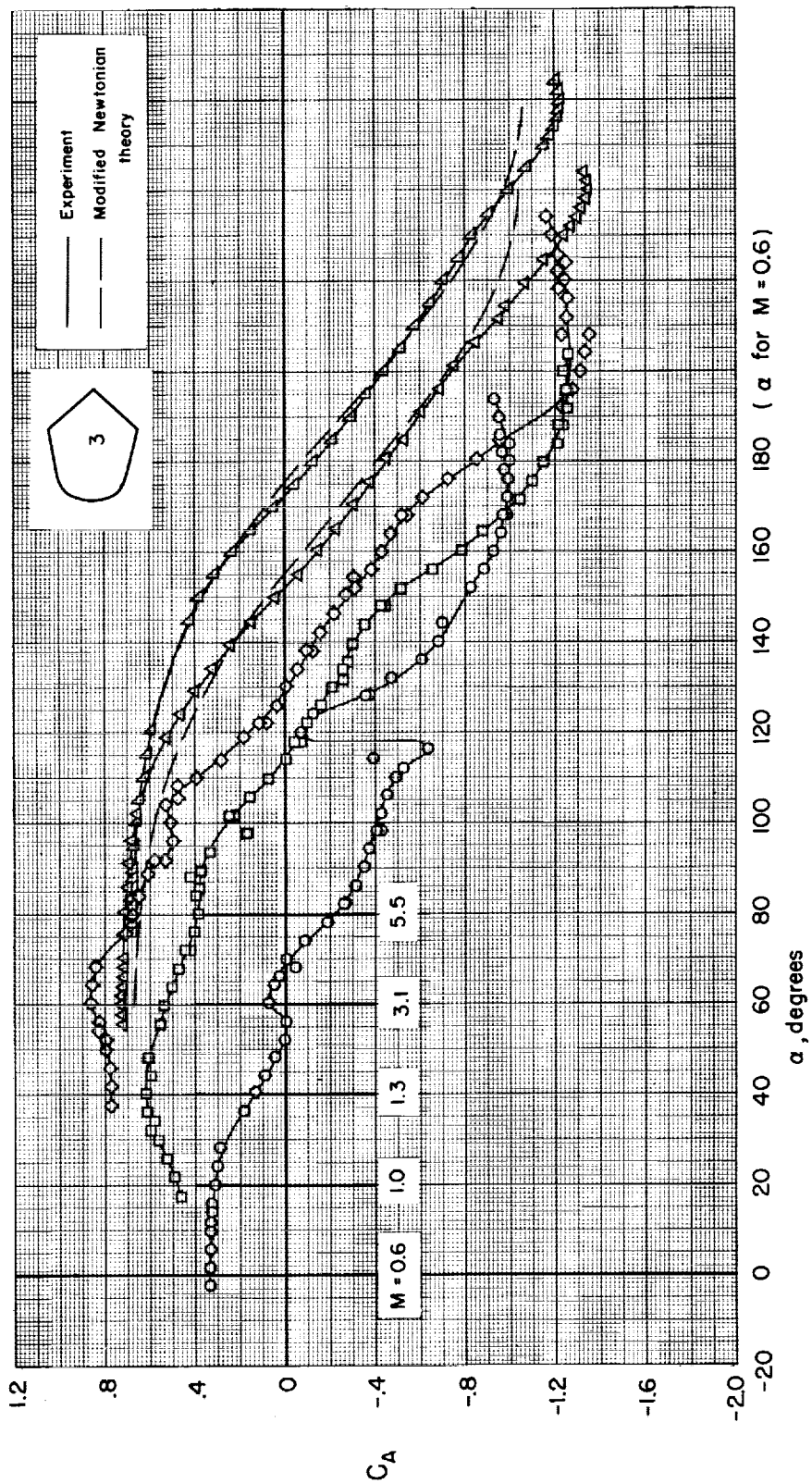
(b)  $C_m$  vs.  $\alpha$ 

Figure 6.- Continued.



(c)  $C_A$  vs.  $\alpha$

Figure 6.- Concluded.

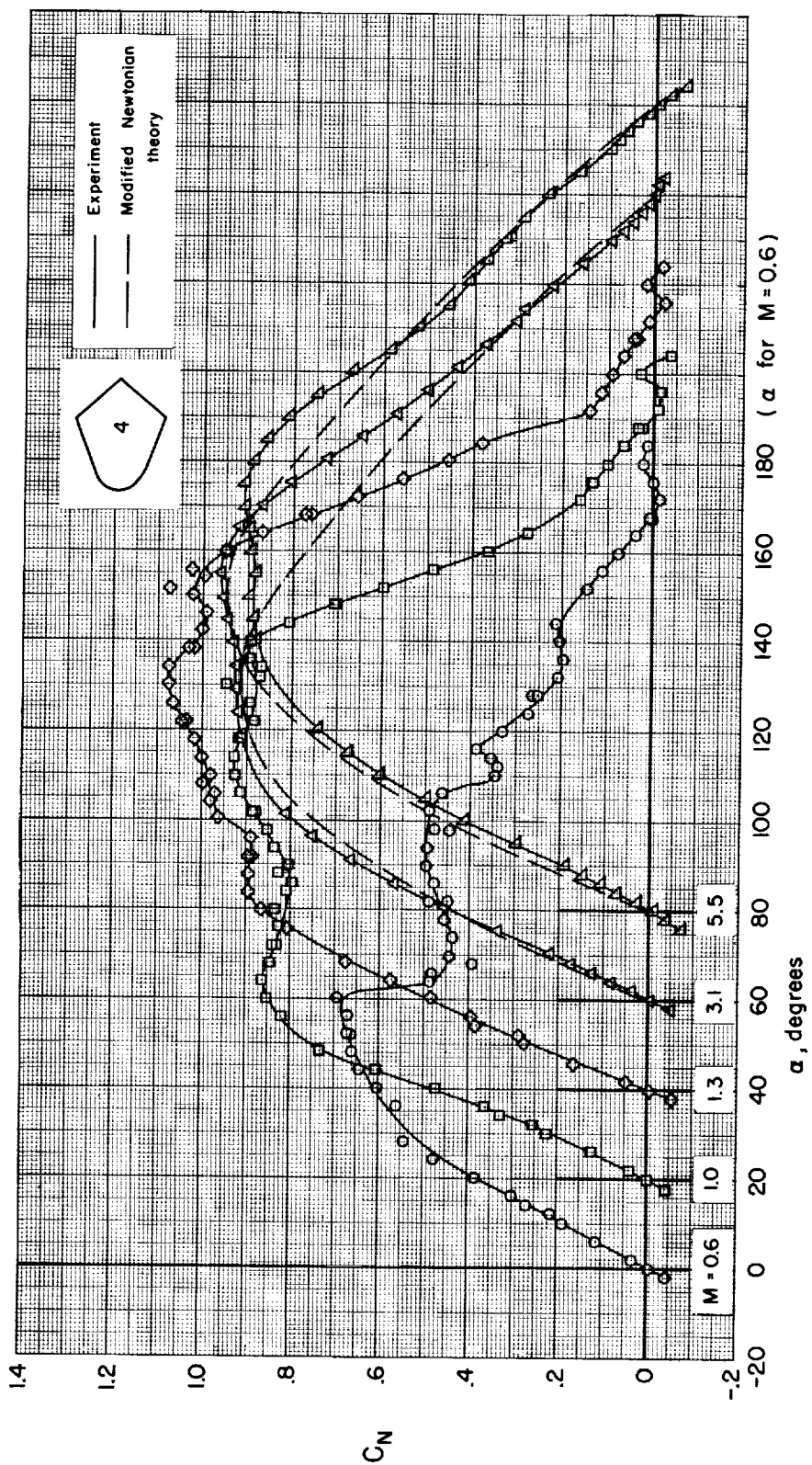
(a)  $C_N$  vs.  $\alpha$ 

Figure 7.- Static aerodynamic coefficients of model 4.

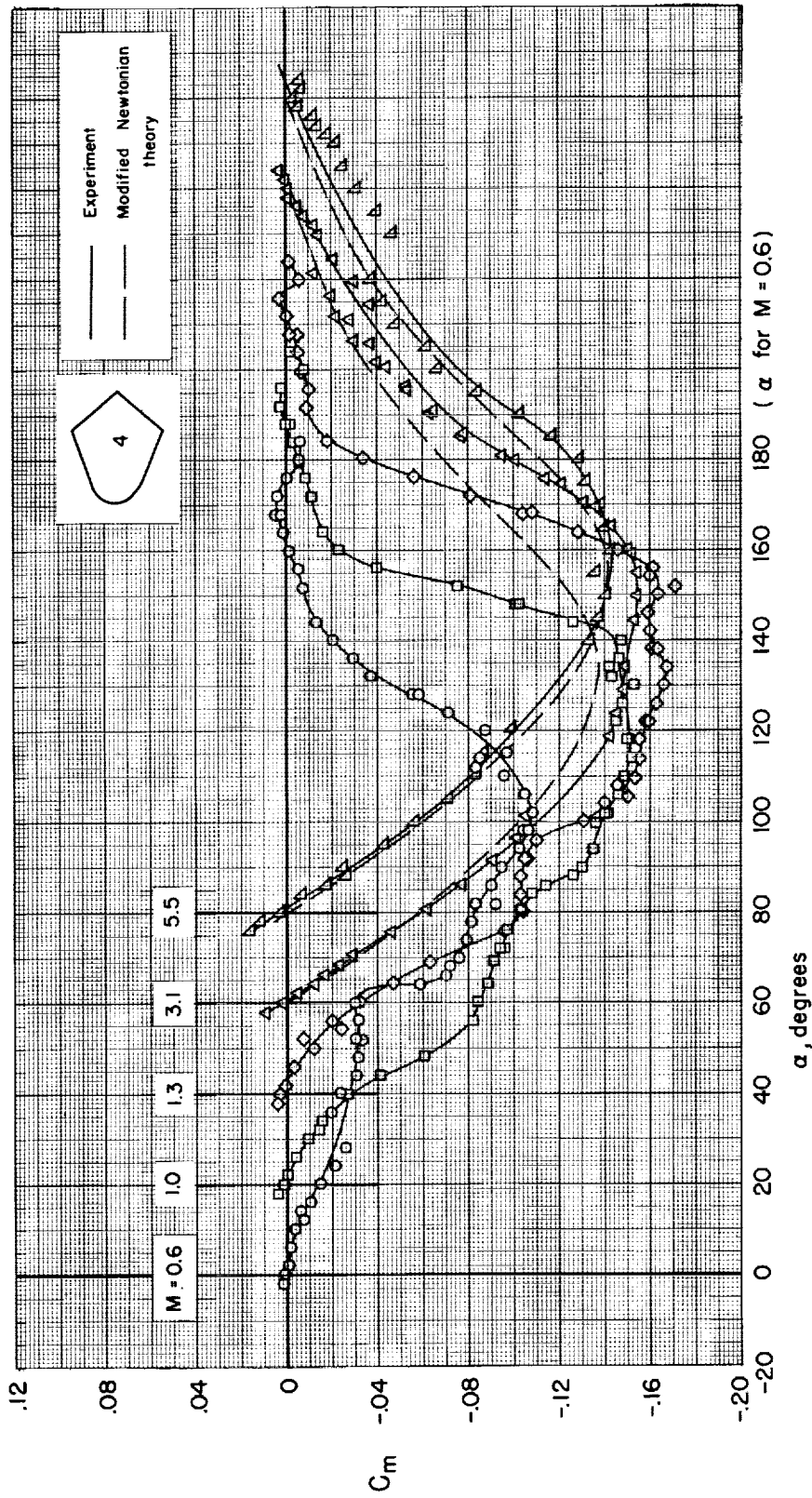
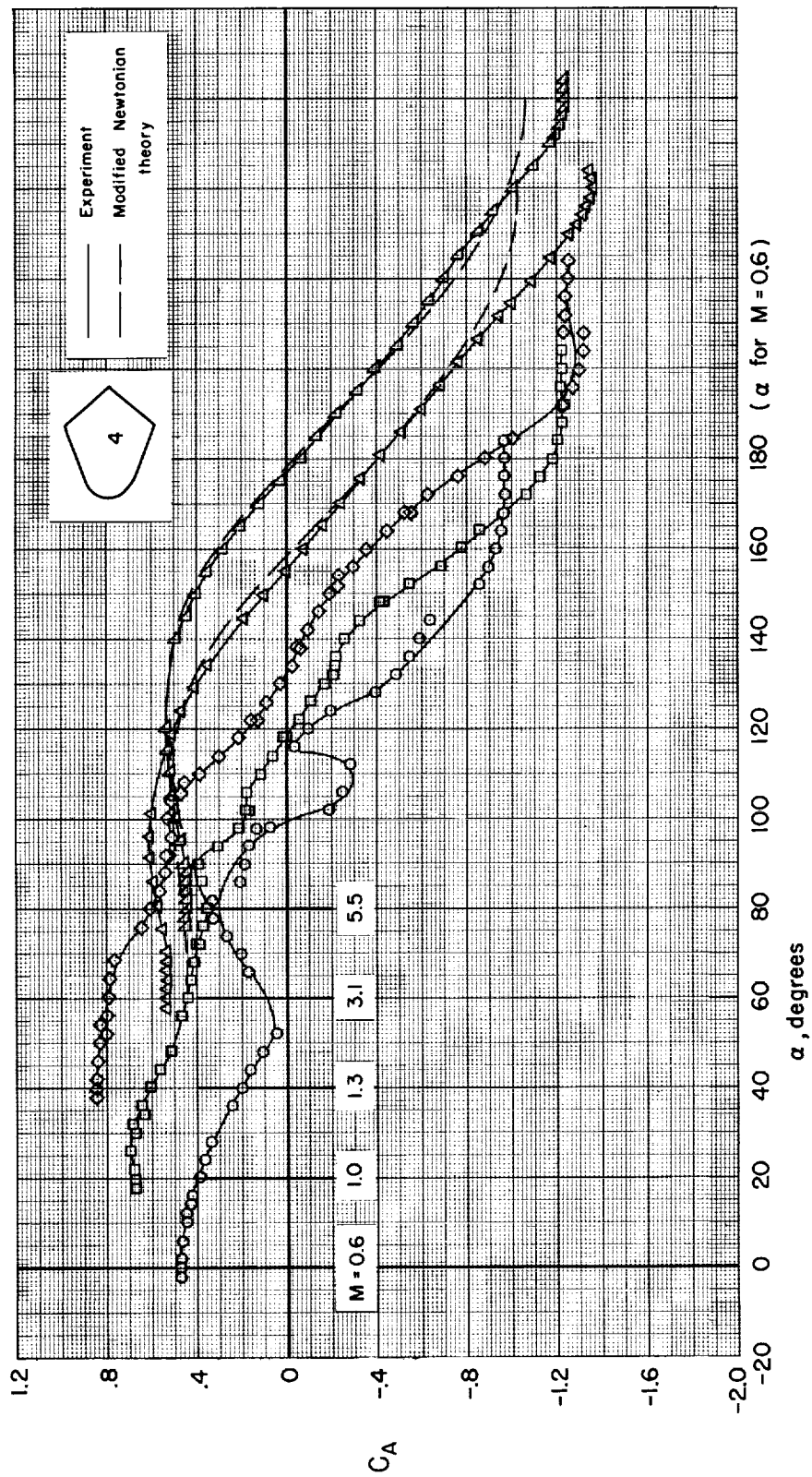
(b)  $C_m$  vs.  $\alpha$ 

Figure 7.- Continued.





(c)  $C_A$  vs.  $\alpha$

Figure 7.- Concluded.

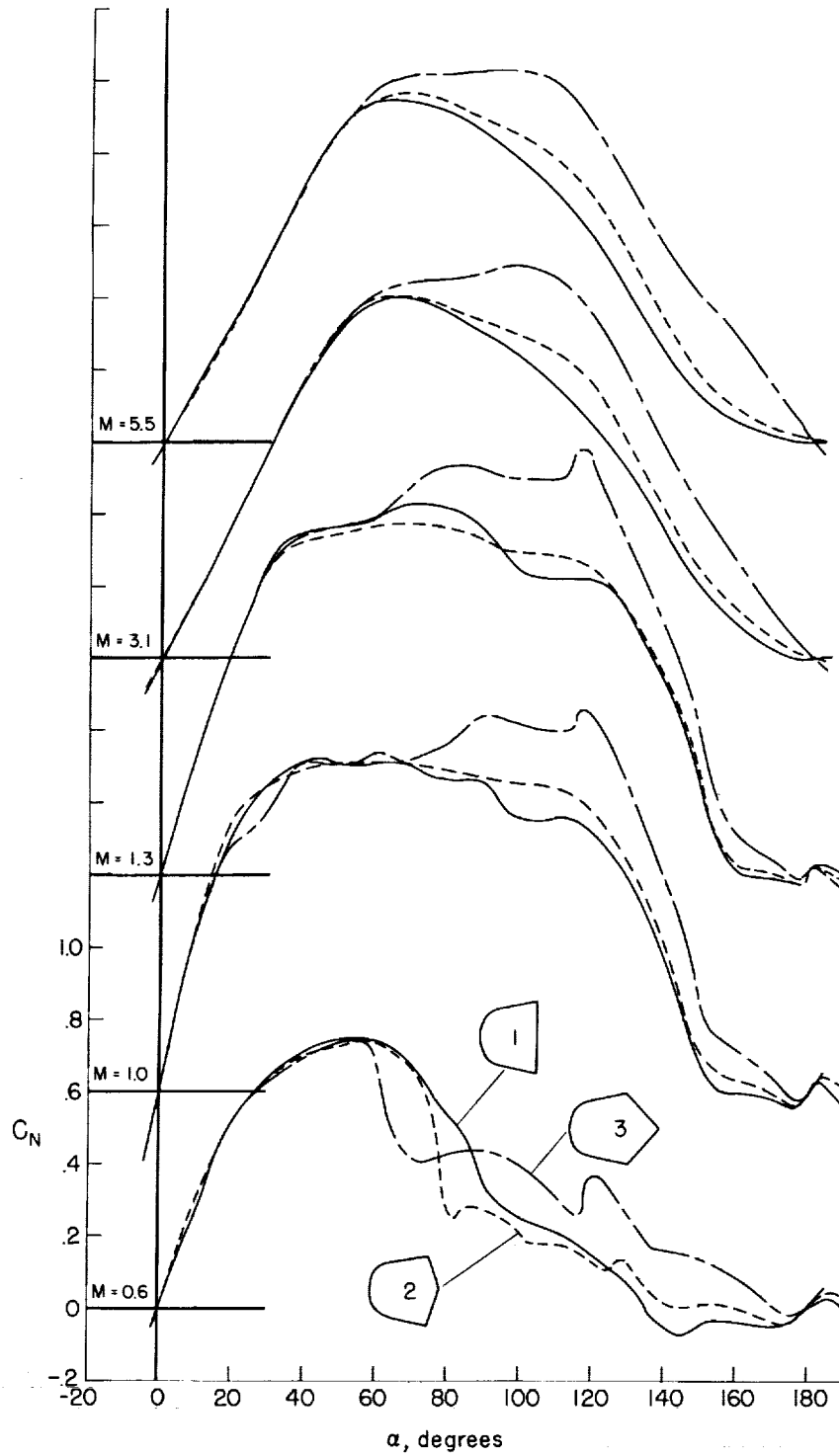
(a)  $C_N$  vs.  $\alpha$ 

Figure 8.- Effects of base shape on the static aerodynamic coefficients.



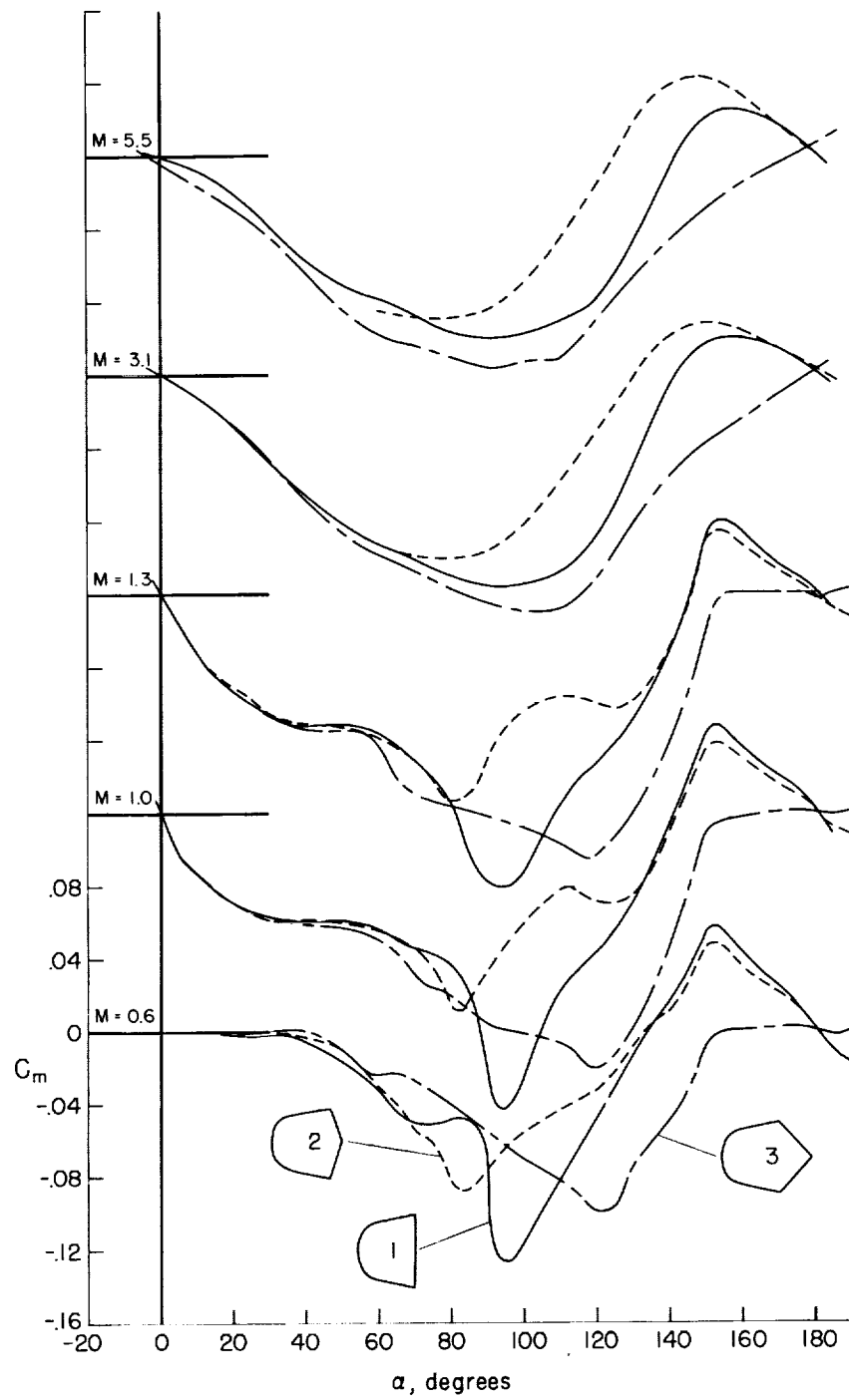
(b)  $C_m$  vs.  $\alpha$ 

Figure 8.- Continued.

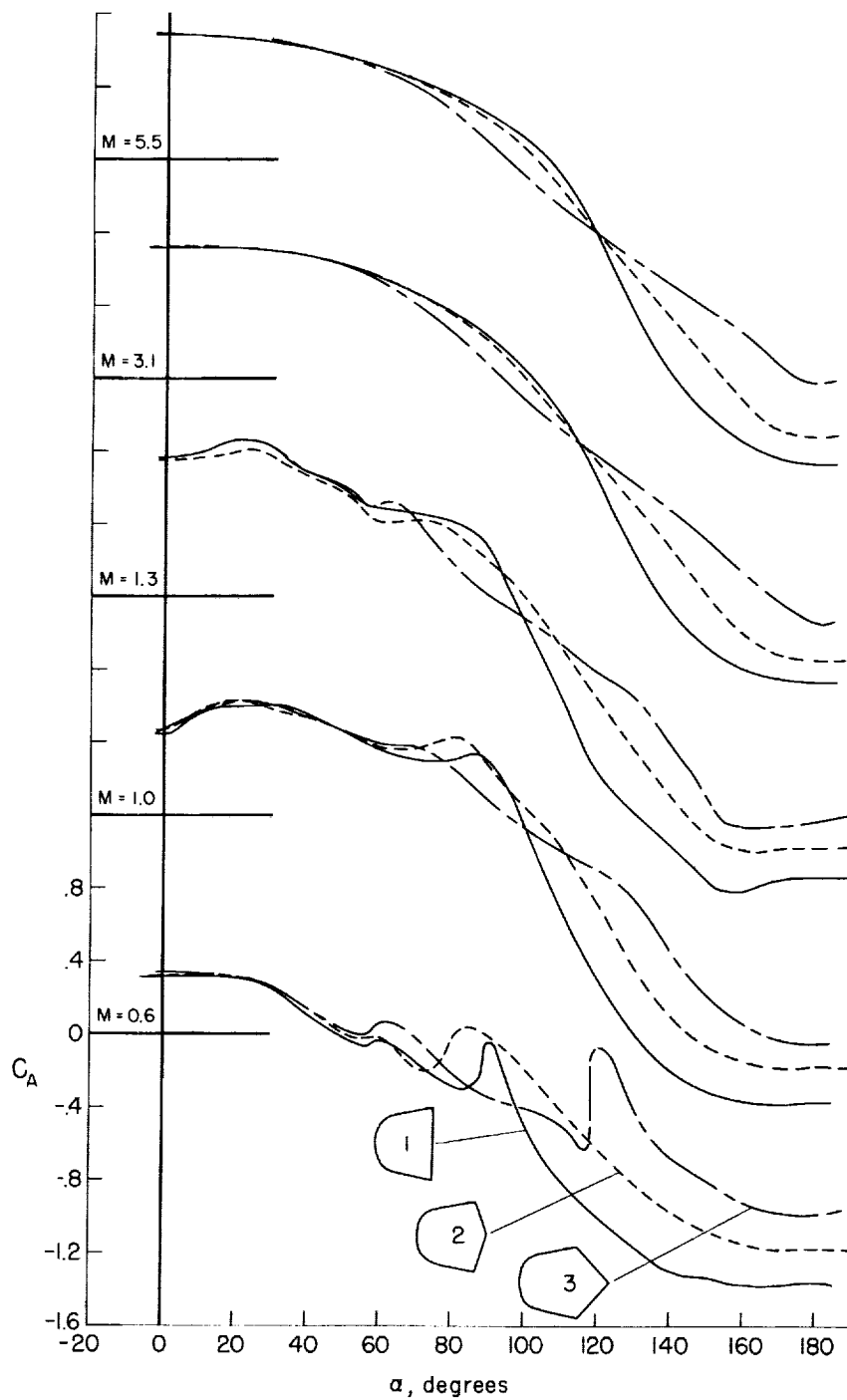
(c)  $C_A$  vs.  $\alpha$ 

Figure 8.- Concluded.

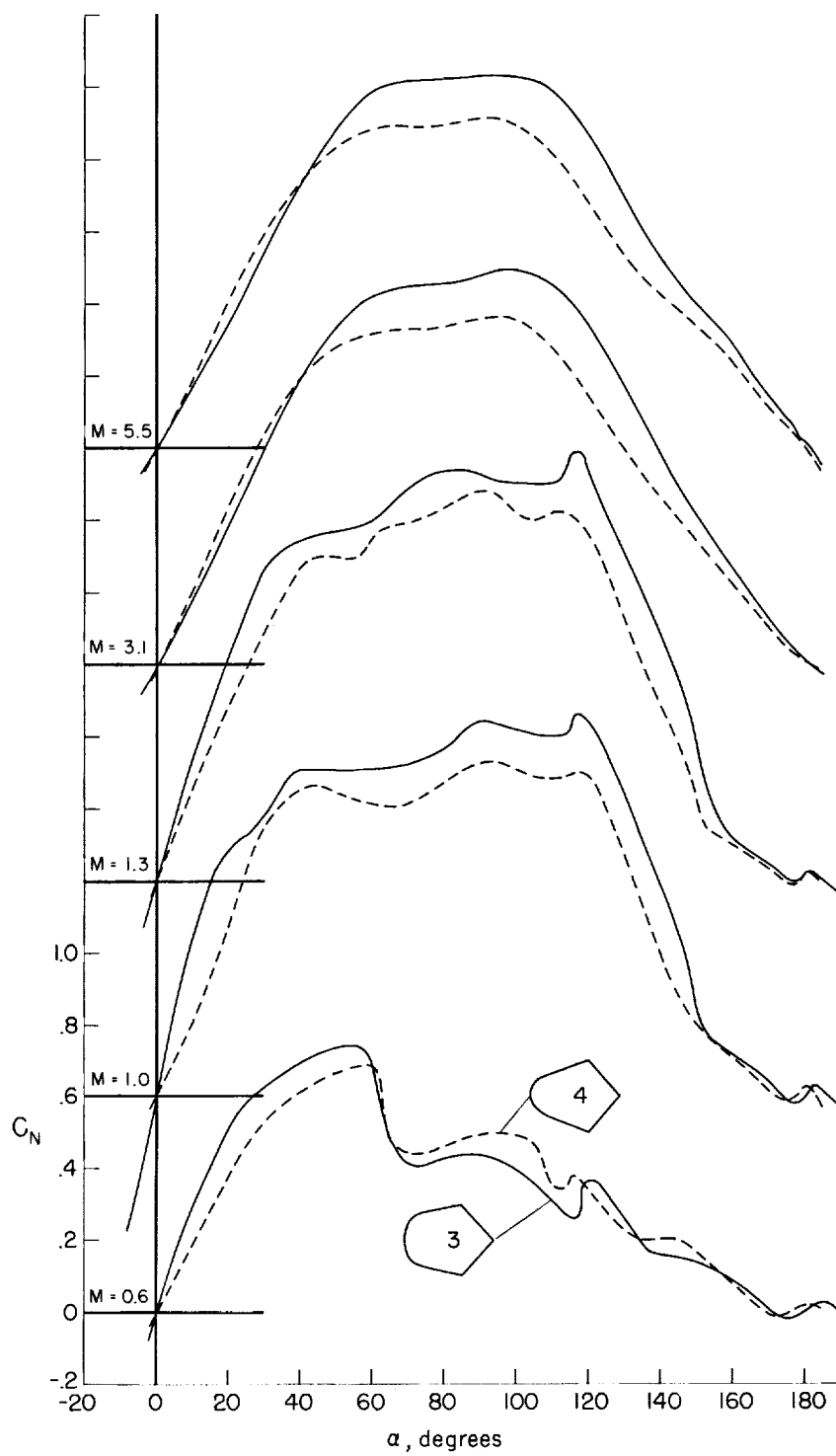
(a)  $C_N$  vs.  $\alpha$ 

Figure 9.- Effects of nose shape on the static aerodynamic coefficients.

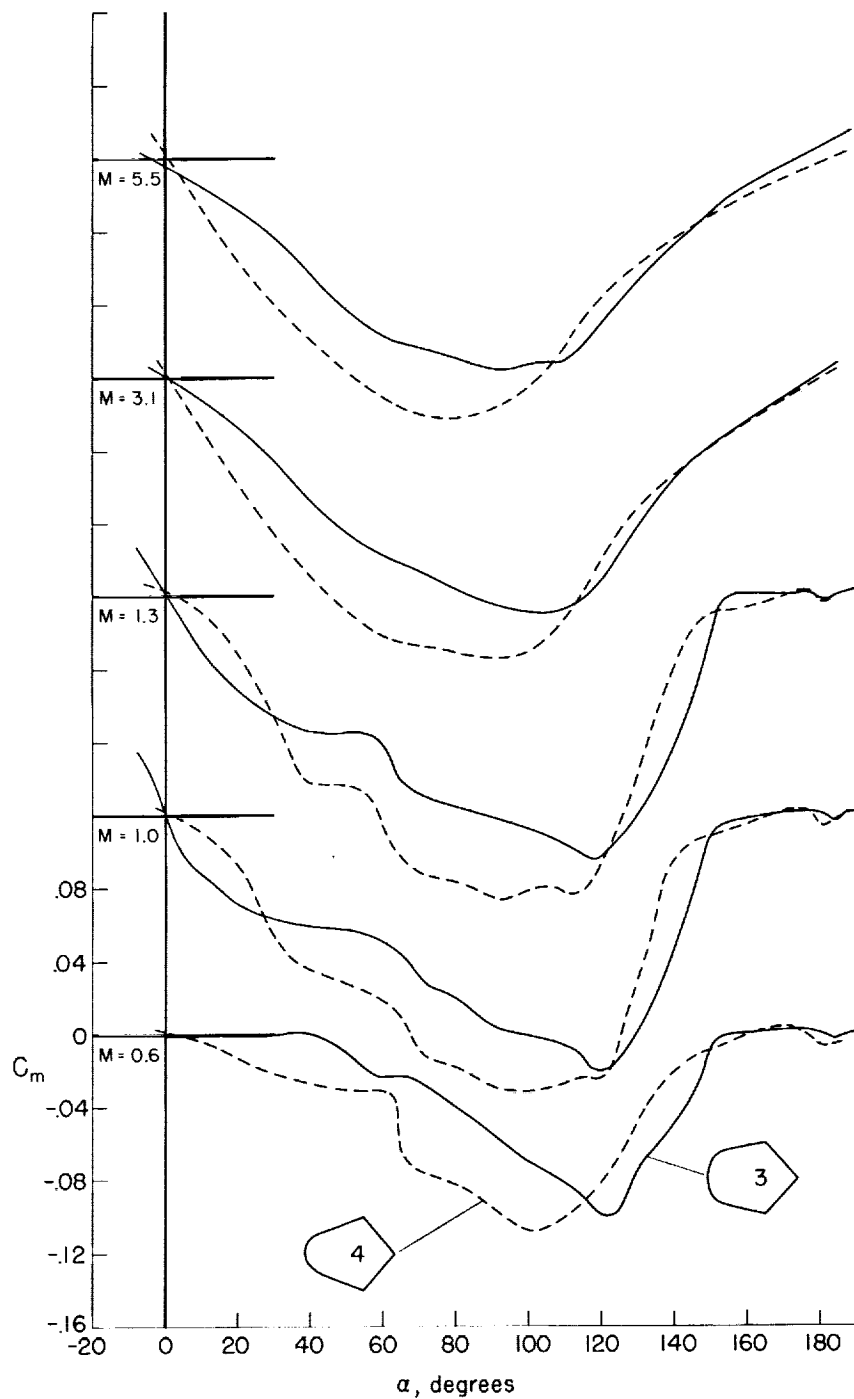
(b)  $C_m$  vs.  $\alpha$ 

Figure 9.- Continued.

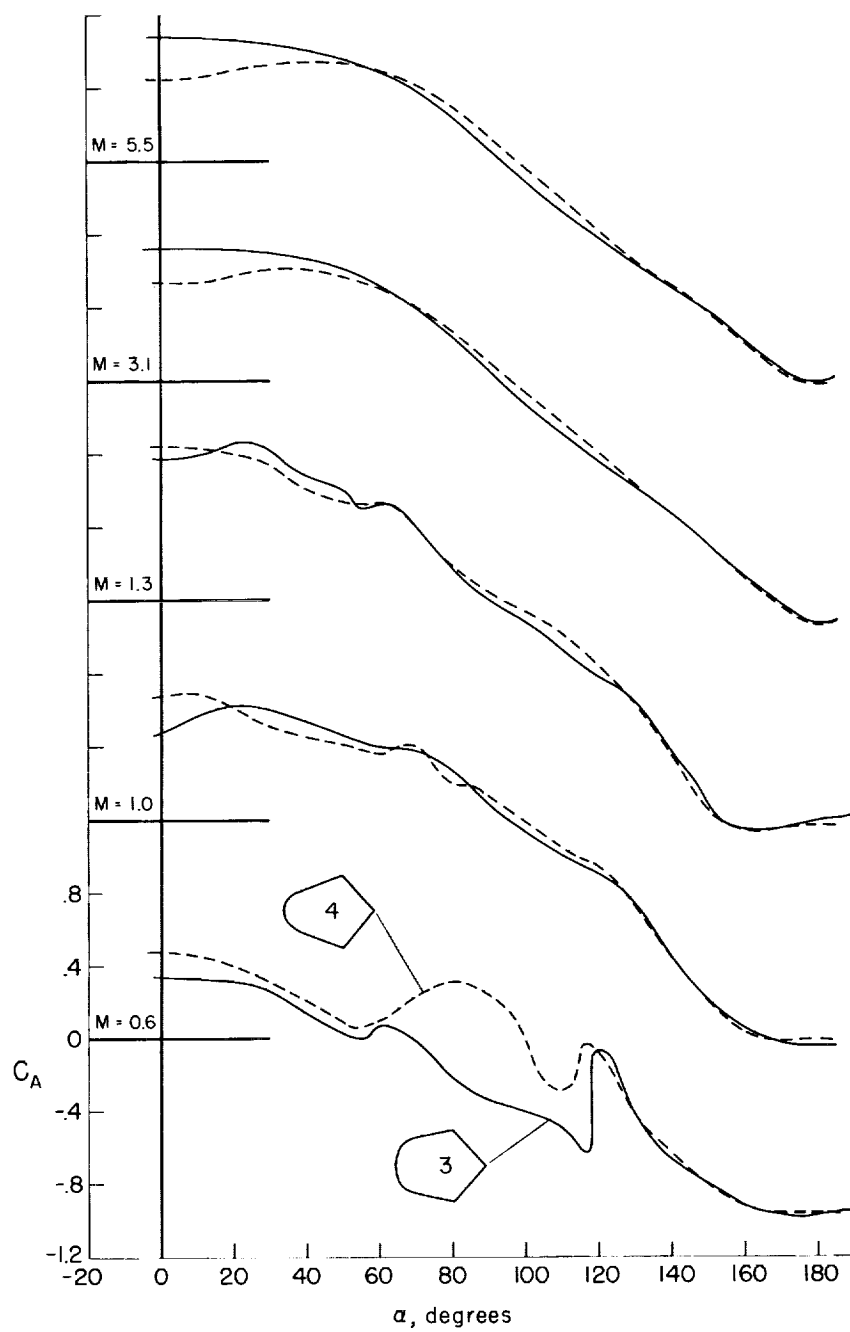
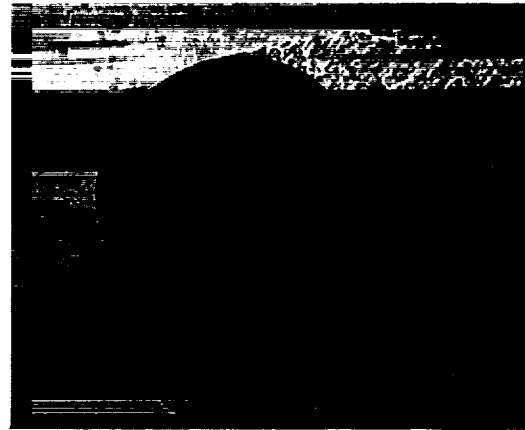
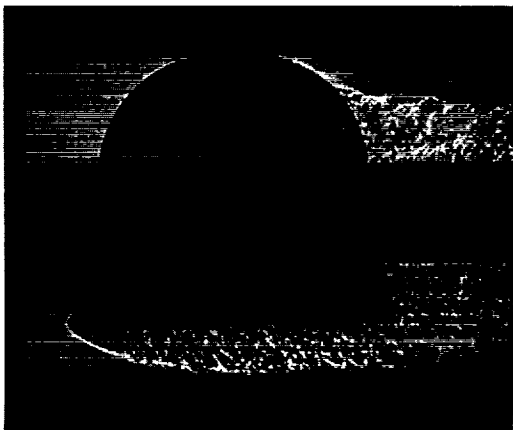
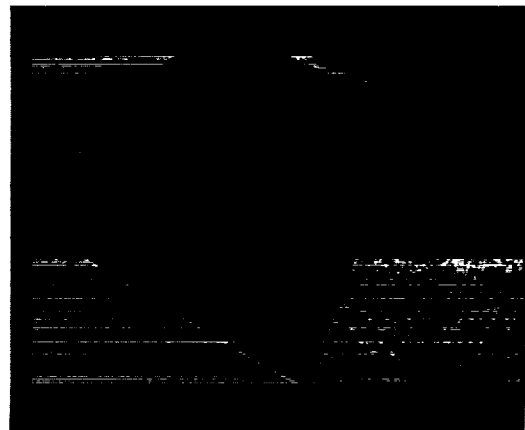
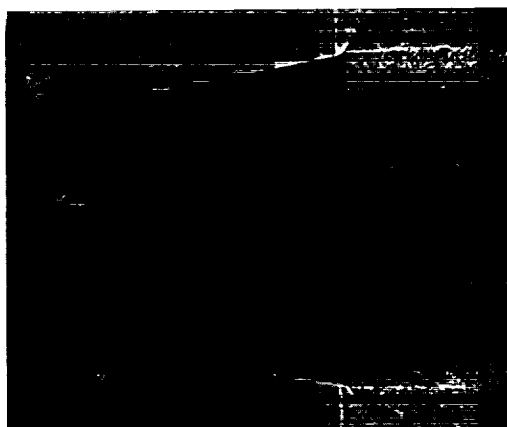
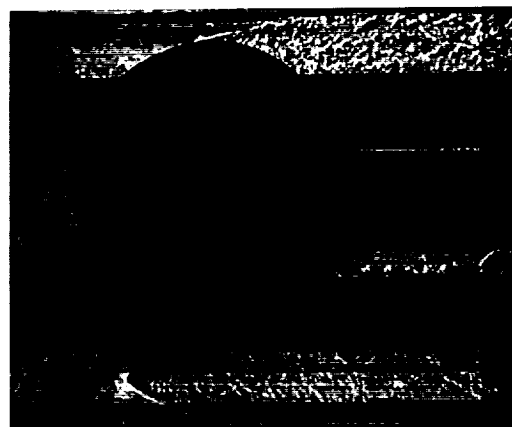
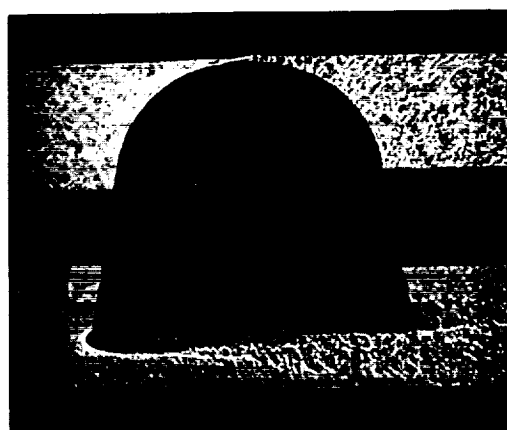
(c)  $C_A$  vs.  $\alpha$ 

Figure 9.- Concluded.


 $\alpha = 0^\circ$ 

 $\alpha = 60^\circ$ 

 $\alpha = 90^\circ$ 

 $\alpha = 120^\circ$ 

(a)  $M = 0.6$

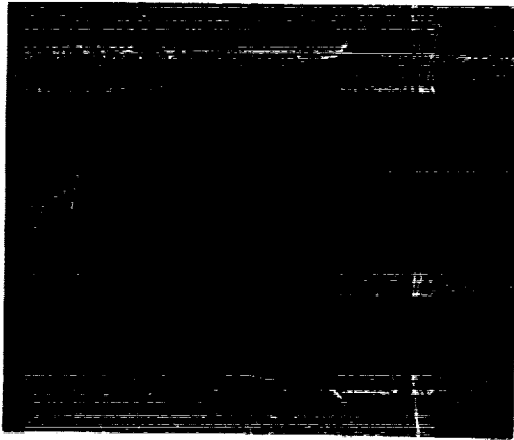
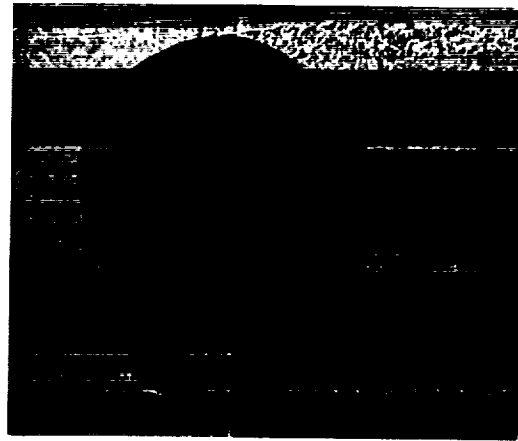
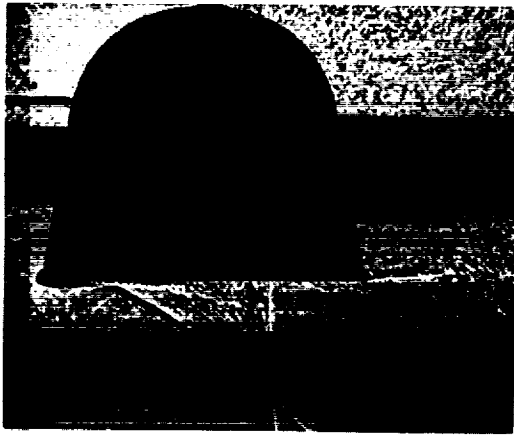
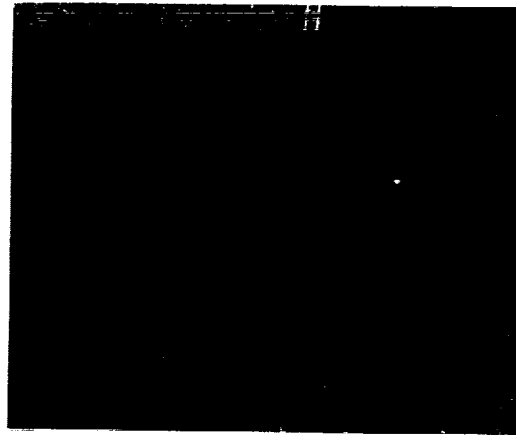
Figure 10.- Shadowgraphs of the flow about model 1.


 $\alpha = 0^\circ$ 

 $\alpha = 60^\circ$ 

 $\alpha = 90^\circ$ 

 $\alpha = 120^\circ$ 

(b)  $M = 1.0$

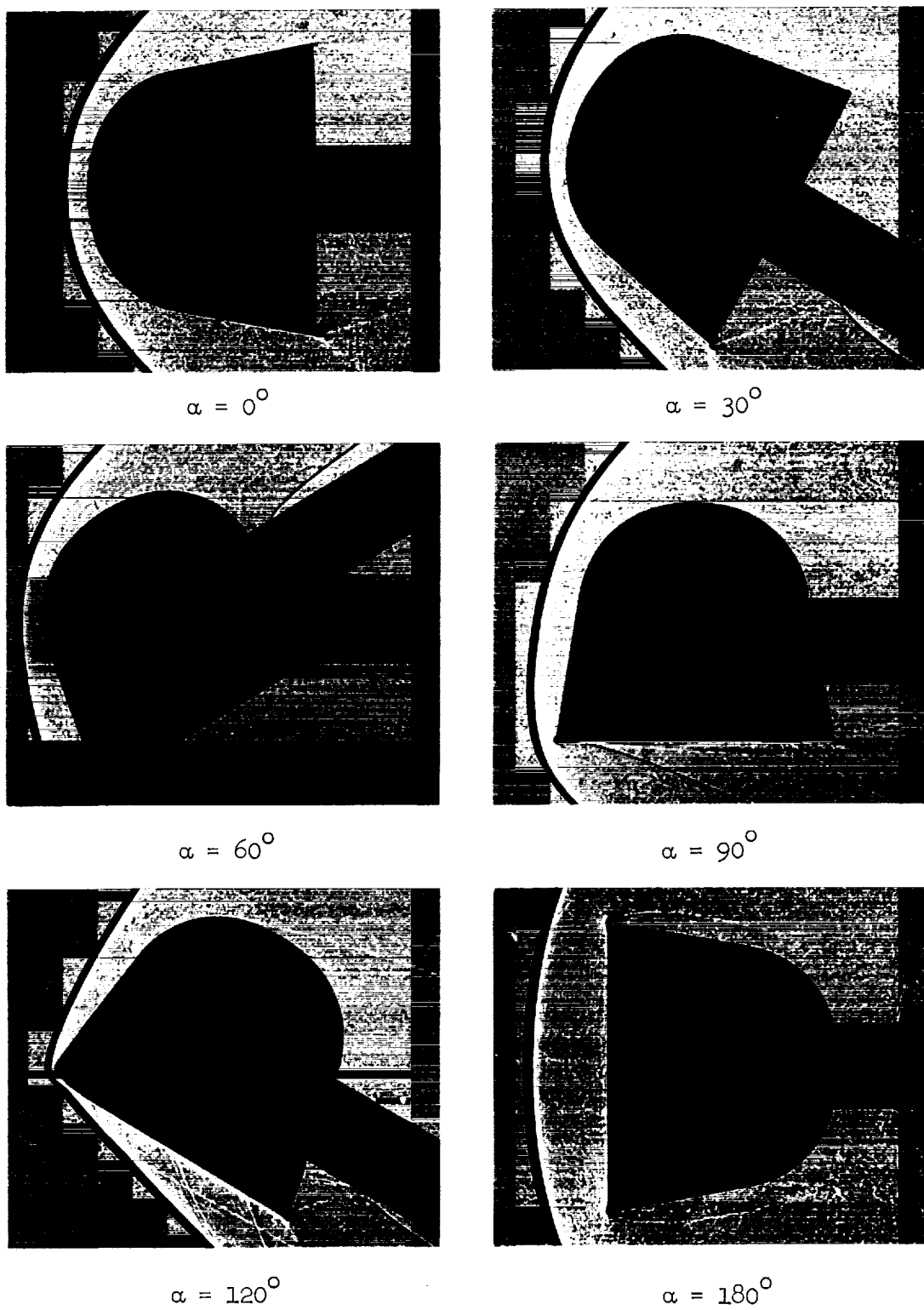
Figure 10.- Continued.


 $\alpha = 0^\circ$ 

 $\alpha = 60^\circ$ 

 $\alpha = 90^\circ$ 

 $\alpha = 120^\circ$ 

(c)  $M = 1.3$

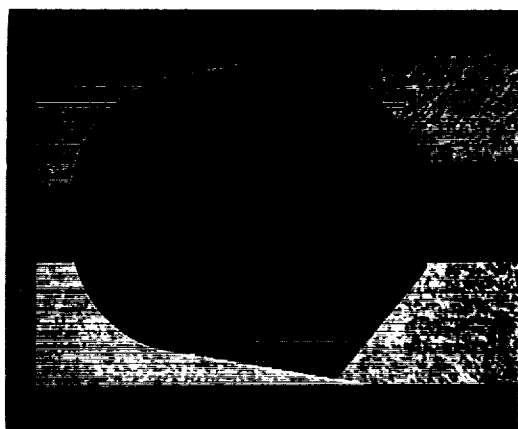
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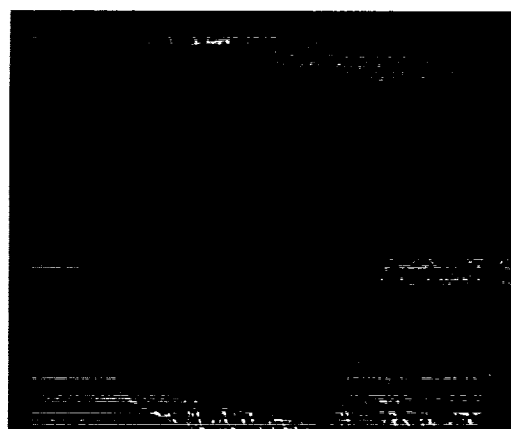


(d)  $M = 3.1$

Figure 10.- Concluded.



$$\alpha = 0^\circ$$



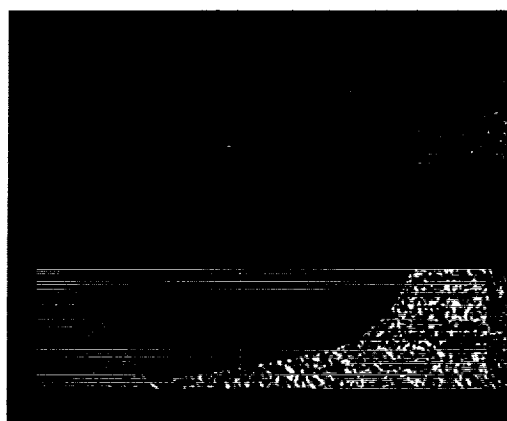
$$\alpha = 60^\circ$$



$$\alpha = 90^\circ$$



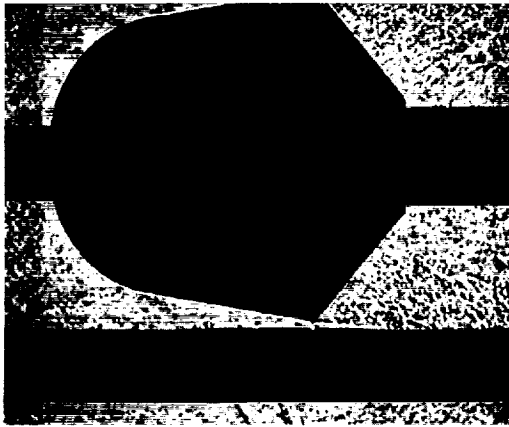
$$\alpha = 120^\circ$$



$$\alpha = 180^\circ$$

(a)  $M = 0.6$

Figure 11.- Shadowgraphs of the flow about model 3.



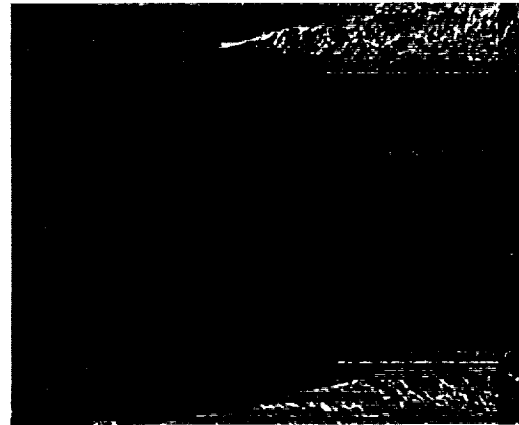
$$\alpha = 0^\circ$$



$$\alpha = 60^\circ$$



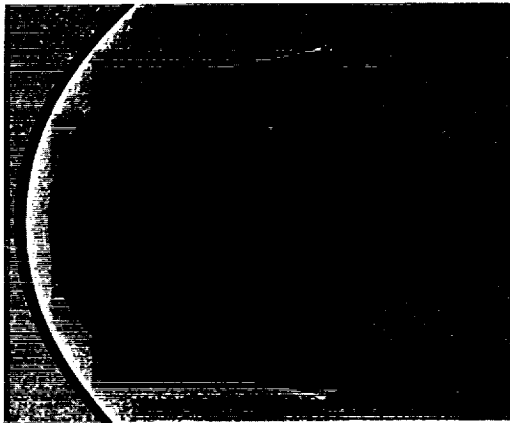
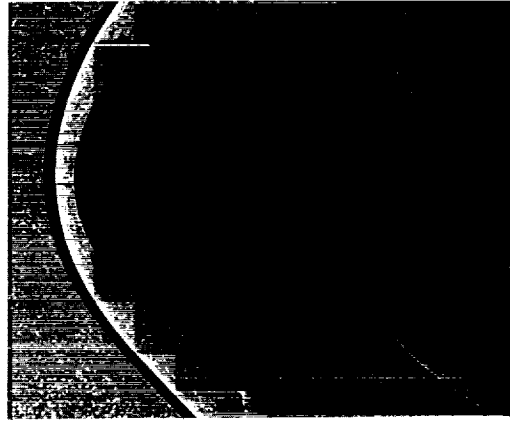
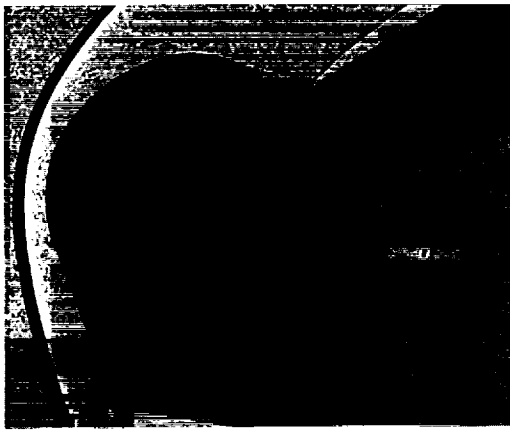
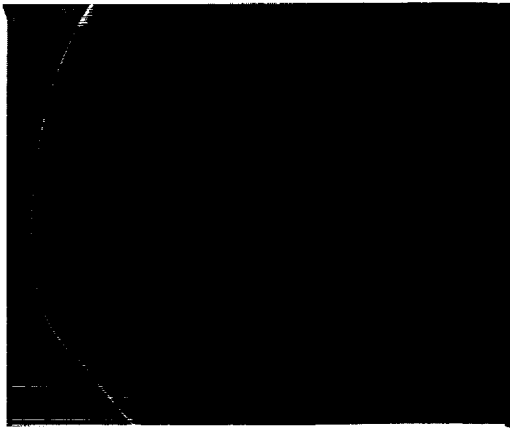
$$\alpha = 90^\circ$$

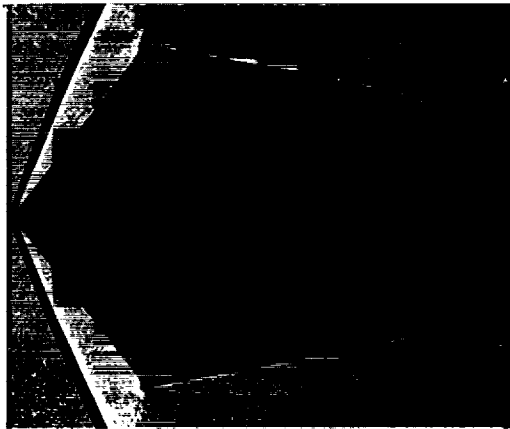


$$\alpha = 120^\circ$$

(b)  $M = 1.0$

Figure 11.- Continued.


 $\alpha = 0^\circ$ 

 $\alpha = 30^\circ$ 

 $\alpha = 60^\circ$ 

 $\alpha = 90^\circ$ 

 $\alpha = 120^\circ$ 

 $\alpha = 180^\circ$ 

(c)  $M = 3.1$

Figure 11.- Concluded.

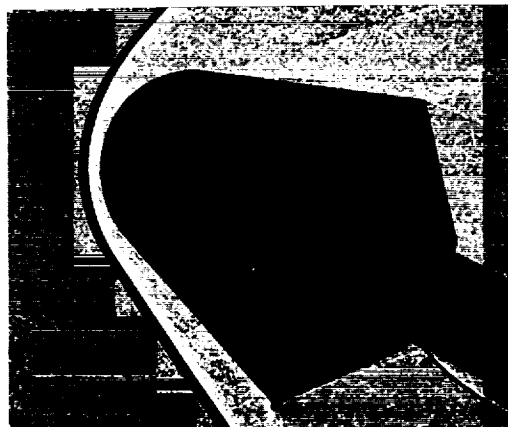
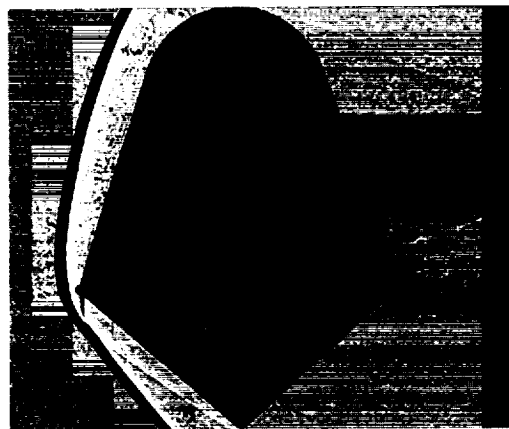
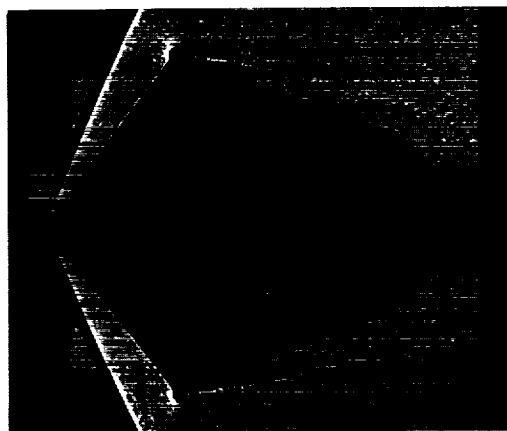
 $\alpha = 0^\circ$  $\alpha = 30^\circ$  $\alpha = 60^\circ$  $\alpha = 90^\circ$  $\alpha = 120^\circ$  $\alpha = 180^\circ$ 

Figure 12.- Shadowgraphs of the flow about model 4 at  $M = 3.1$ .



<p>NASA TN D-1327 National Aeronautics and Space Administration. STATIC AERODYNAMIC CHARACTERISTICS OF SHORT BLUNT CONES WITH VARIOUS NOSE AND BASE CONE ANGLES AT MACH NUMBERS FROM 0.6 TO 5.5 AND ANGLES OF ATTACK TO 180°. Stuart L. Treon. May 1962. 35p. OTS price, \$1.00. (NASA TECHNICAL NOTE D-1327)</p> <p>Short blunt cones having nose half-angles of 10° and 20° were investigated. The model with the 10° nose half-angle was tested with a flat base and with base cones of 50° and 70° half-angle. The 20° nose cone half-angle model had a 50° half-angle base cone. Reynolds number ranged from 0.6 to 1.8 million based on the model maximum diameter. Estimates of the aerodynamic coefficients were made by means of a modified Newtonian theory.</p>	<p>I. Treon, Stuart L. II. NASA TN D-1327</p> <p>(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 20, Fluid mechanics; 48, Space vehicles; 50, Stability and control.)</p>	<p>NASA TN D-1327 National Aeronautics and Space Administration. STATIC AERODYNAMIC CHARACTERISTICS OF SHORT BLUNT CONES WITH VARIOUS NOSE AND BASE CONE ANGLES AT MACH NUMBERS FROM 0.6 TO 5.5 AND ANGLES OF ATTACK TO 180°. Stuart L. Treon. May 1962. 35p. OTS price, \$1.00. (NASA TECHNICAL NOTE D-1327)</p> <p>Short blunt cones having nose half-angles of 10° and 20° were investigated. The model with the 10° nose half-angle was tested with a flat base and with base cones of 50° and 70° half-angle. The 20° nose cone half-angle model had a 50° half-angle base cone. Reynolds number ranged from 0.6 to 1.8 million based on the model maximum diameter. Estimates of the aerodynamic coefficients were made by means of a modified Newtonian theory.</p>	<p>I. Treon, Stuart L. II. NASA TN D-1327</p> <p>(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 20, Fluid mechanics; 48, Space vehicles; 50, Stability and control.)</p>	<p>NASA</p>
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